A PROCESS APPROACH TO PRESENTISM

A ROUTE TOWARDS COMPATIBILITY WITH PHYSICAL THEORY

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ABSTRACT

The aim of this thesis is to develop an approach to presentism that is compatible with physical theory. Central to the achievement of this aim is the development of a suitable ontology for presentism, one that succeeds in internalising the objectively dynamic features of reality. This requires a radical approach to certain entrenched assumptions concerning time, persistence and change that are embedded in the standard metaphysical paradigms within which current debates within the philosophy of time take place.

The principal premise of the thesis is that presentism is *primarily* an ontological thesis concerning the nature of existence, rather than a thesis about the nature of time *per se*. In particular, I take 'serious' presentism to involve a combination of the thesis that only present things exist, with the thesis that reality is objectively dynamic. A secondary premise of the thesis is a denial that time is substantival. I garner support for this latter premise from consideration of the 'problem of time' within quantum gravity and the role played by the concept of time in both general relativity and quantum mechanics. This provides a route towards an account of presentism compatible with physical theory, namely one that equates time with the structure of an objectively dynamic reality.

If time is derivative of an objectively dynamic reality, then this has implications for the standard accounts of both change and persistence. The key to developing an adequate ontology for presentism requires that both change and persistence are formulated independently of (B-series) time. The path to achieving this requires a determination of the objective correlates of tense; on this basis I argue for a reformulation of persistence as 'continuing existence' and for real, metaphysical change to be defined in terms of objective creation and annihilation. I further argue that, for the 'serious' presentist, real change and persistence are metaphysically primitive, and so need to be reflected within the category structure of an appropriate ontology.

I propose an ontological model based on the categories of pure process (which exemplifies persistence) and interaction event. Interaction events are defined as interactions of pure processes that result in the creation or annihilation of pure

processes; events thereby reflect real, metaphysical change. I utilise a functional alignment of the categories of the proposed ontology with the primitive elements of Belkind's (2012) Primitive Motion Relationism to argue for the compatibility of the proposed presentist ontology with relativistic spacetime. In the final chapters I seek to show how the proposed ontological model might assist the presentist in tackling particular problems, such as formulating a successful account of objective becoming, accounting for cross-temporal causal relations, and the asymmetry of fixity.

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INTRODUCTION

The overarching aim of this thesis is to establish the groundwork for an account of presentism that is compatible with physical theory. In pursuing this aim the principal argument of the thesis is that a process model of presentism is the best option.

I believe that presentism is true. I also believe that our best theories of physics indicate important truths about reality at the fundamental level. Given this, a successful account of presentism must be compatible with those theories. A core argument of this thesis is that the route to achieving compatibility requires a model of presentism that succeeds in *internalising* the objectively dynamic aspects of reality. By 'internalising' I mean modelling the dynamic aspects of reality independently of B-series time. The principal motivation for the approach taken is the belief that a suitably constructed process ontology permits the presentist to achieve precisely this.

To my knowledge a process account of presentism has not been previously attempted. Indeed, at first glance a process ontology appears incompatible with presentism. The reason for this is that processes are generally considered to be temporally extended. As Rescher (1996) states, 'it is of the very essence of an ongoing process that it combines existence in the present with tentacles reaching into the past and the future' (p.39). The incompatibility is clear. Presentism is the view that 'only present things exist' (Ingram and Tallant, 2018, Introduction). If processes have 'tentacles' reaching into the past and future, the present existence of the process brings with it a commitment to the existence of its past and future components, contrary to presentism.

The challenges presented by this apparent incompatibility require one to question certain entrenched assumptions that underpin the standard metaphysical paradigms within which current debates in the philosophy of time take place. It also demands a radical approach that critically examines our intuitions about, and concepts of, time, persistence and change. A key assumption to be questioned is that a dynamically evolving reality has to be formulated in 3+1 dimensional terms,[1] such models imply a commitment to absolute simultaneity, in opposition to the results provided by the Special Theory of Relativity.

In approaching this thesis, I 'hang my hat' on a species of naturalism. I consider this as subscribing to a commitment to ontological realism (i.e. that objective reality is independent of human conception and representation) and to the idea that concrete[2] reality is physical and, more or less, successfully modelled by our best scientific theories. As such I consider that the primary role of the metaphysics of time is to describe the *de facto* nature of concrete reality, how it is in this universe, rather than how it might be in other possible universes. In addition, the arguments within this thesis are intended to appeal to those presentists who subscribe to the view that tense reflects a fundamental truth about reality, namely that reality exemplifies objective passage, or becoming.[3] I describe this view as 'serious presentism'.

I begin the thesis by arguing that the establishment of a 'compatibilist'[4] account of presentism is severely disadvantaged by the terms of the debate within the philosophy of time, the historical roots of which can be traced back to pre-Socratic philosophy (Chapter 1). Key to understanding the root cause of the difficulties is to recognise that the opposing theories of time (principally presentism and eternalism) should be critically evaluated with reference to the wider metaphysical paradigms within which these theories sit; I describe these as the 'static' and 'dynamic' models of reality. The theories of time associated with each model bring with them implicit assumptions concerning change and persistence, and the metaphysical dependencies that hold between them. Nonetheless, I argue that *both* the opposing metaphysical models share a common false presupposition; this is the presupposition that time is

[1] A '3+1 dimensional' ontology of spacetime is one that asserts an absolute, objective division of spacetime into separate spatial (3) and temporal (1) dimensions, in contradiction to the Special Theory of Relativity. The assumption that the presentist is committed to this stance is made, for example, in Craig (2008), Nasmith (2011), Hawley (2006, p.451), Monton (2006, p.2).
[2] By 'concrete' I mean existing spatiotemporally.
[3] I accept that presentism (the view that 'only present things exist') is compatible with a denial that reality exemplifies objective passage.
[4] When used to describe an account of presentism, the term 'compatibilist' is shorthand for 'compatible with our best physical theories'.

substantival and metaphysically independent from the existence of entities. This has the consequence that change and persistence are assumed to be metaphysically dependent on, or derivative of, substantival time.

This common false presupposition seriously disadvantages the presentist (and indeed any dynamic theorist) in two ways. First, it engenders the assumption that objective becoming can only be formulated as *temporal* becoming; objective becoming is *in* time or *of* time. And temporal becoming, conceived either as the flow of time itself or as the possession of transitory tensed properties, leads to McTaggartian problems of contradiction or infinite regress. It also obstructs the formulation of an account compatible with physical theory. Where temporal becoming requires a unique, universal time, with respect to which reality evolves, this commits the dynamic theorist to a 3+1 dimensional conception of reality, in direct opposition to our best physical theories.

The solution to these problems is for the presentist to establish a mechanism by which the dynamic aspects of reality are *internalised* and made independent of time. The 'serious' presentist, the presentist for whom reality is objectively dynamic, should therefore subscribe to a reversal of the order of metaphysical priority between time, on the one hand, and both change and persistence, on the other.

Although presentism is primarily regarded as a theory of *time* its principal thesis is that 'only present things exist' and, for the serious presentist, this thesis is combined with a commitment that tense reflects a fundamental, objective feature of reality. Neither claim, as such, makes ostensive reference to time. This leads to the thought that presentism is *primarily* an ontological thesis concerning the nature of existence, rather than a thesis about the nature of time *per se*. Consequently, Chapter 1 concludes that a compatibilist theory of presentism, and one able to achieve an internalisation of the dynamic aspects of reality, should be constructed on two foundational premises. The first premise is the 'thesis of objective passage' (P1). This is the thesis that tense reflects the fact that reality exhibits objective passage that is grounded, in some manner, in its intrinsically dynamic nature. The second premise (P2) is the premise that time reduces to the structure of an objectively dynamic reality. The presentist should therefore subscribe to a reductionist, or relational, account of time. The task of Chapter 2 is to provide arguments in support of both these foundational premises. In Chapter 3 I address, head-on, the charge that it is eternalism, rather than presentism, that is better supported by our best theories of physics. The subsequent chapters are concerned with constructing the main body of a compatibilist account of presentism.

In Chapter 2 I justify a reductionist account of time (premise P2) by garnering support from physical theory; in particular, with reference to the 'problem of time' within emerging theories of quantum gravity. In assessing the role played by the concept of time within both general relativity theory (GTR) and quantum mechanics, I argue that a 'reductionist structuralism' with respect to the spacetime of GTR provides the best way of understanding this role. Further, a consensus of opinion suggests that such a view of time provides the key to resolving certain conceptual issues that obstruct the development of a successful account of quantum gravity. A review of how time is defined, both historically and within current physical theories, lends support for the premise that time is derivative of objective change in reality; there is nothing within physics to support a denial, of premise P1, that reality is objectively dynamic. I conclude that it is beneficial for the presentist to equate (B-series) time with the structure of an intrinsically dynamic reality, as this provides the best route towards developing a compatibilist account.

Presentism implies a rejection of ontological parity. Since eternalism, with its commitment to ontological parity, is generally considered to be well-supported by the Special Theory of Relativity (STR), it needs to be shown that the ontological commitments of presentism are compatible with relativistic physics and this is the task of Chapter 3. This chapter reviews the 'Rietdijk-Putnam-Penrose' arguments to eternalism, from the relativity of simultaneity, and critically assesses a more recent formulation from Peterson and Silberstein (2010). I argue that this reformulation fails on the grounds that it begs the question in support of eternalism. I then consider an alternative argument that eternalism stands as inference to the best explanation of relativistic effects. I reject this argument on the grounds that it relies upon an erroneous assumption of an absolute coincidence between spatiotemporal coordinates in different observers' reference frames, an assumption only made plausible by confounding the concepts of coordinate points and spatiotemporal events. I suggest a better explanation of relativistic effects aligned with the commitments of presentism. Key to this is understanding that there is nothing within the meaning of 'existing four dimensionally', within the STR, that is incompatible with presentism. As such, relativistic kinematic effects are compatible with a presentist position that regards four dimensional spacetime as the structure of an objectively dynamic reality.

In developing a compatibilist model of presentism, that regards spacetime as the structure of reality, a potential objection rears its head. A structuralist account of time is equally open to the eternalist, and this leads into a recent, sceptical debate that questions whether there is any metaphysical substance to the disagreement between the presentist and the eternalist (e.g. Dorato, 2006b). This debate is important, and critical analysis (Chapter 4) reveals that the terms within which it is conducted serve to disadvantage the presentist's case. In particular, the sceptical claim relies upon semantics and formulates the debate in terms of tensed and tenseless existence claims. This conceals the ontological heart of the disagreement and generates the 'presentist's dilemma' (Meyer, 2013, p.69): attempts at a formulation of presentism are rendered either 'trivially true or obviously false'.

I argue that the ontological substance of the debate between the presentist and eternalist turns on the *nature of what it is* that makes the relevant existence claims true. Specifically, for the eternalist occurrence at a particular spatiotemporal location is a sufficient determinant of concrete existence; this is not the case for the presentist. For the presentist, the truthmaker for the relevant existence claim is the fact that the entity exists *now*. This supports the position that presentism needs to be formulated on a more fundamental, ontological level, independently from reference to any present 'time'. Tallant's (2014) Existence Presentism achieves this. In asserting an identity between presence and existence, it removes any metaphysical dependence between the present and a unique B-series time. In doing so it appears to be the only recent formulation of presentism able to circumvent successfully the 'presentist's dilemma' and thereby establish that the debate between the eternalist and the presentist is not only an ontologically significant one, it is one that concerns the *nature* of existence.

In separating existence from B-series time, Existence Presentism provides scope for developing a reductionist-structuralist model of spacetime, aligned with presentism, where spacetime is metaphysically derivative of an objectively dynamic reality. Nonetheless, significant challenges arise in relation to modelling an objectively dynamic reality independently from (B-series) time and this requires development of suitable accounts of both persistence and change for the serious presentist.

In Chapter 5 I consider the suitability and utility of the standard accounts of persistence and change for the compatibilist model of Existence Presentism being developed. I argue that the separate commitments of Existence Presentism and compatibility with physical theory imply two criteria for suitable accounts of persistence and change: first, that change and persistence are formulated independently of B-series time and, second, that any definition of change is consistent with real, 'metaphysical change' (after Pezet, 2017, p.1824). The latter is the notion that 'the whole of what exists is changing', and I argue that this position is implied if reality is 'objectively tensed'.[5] I argue that the standard accounts of persistence (endurance and perdurance) fail to meet either of these criteria and so are unsuitable for the compatibilist Existence Presentist. The source of the problems is that, under both models, persistence is grounded in transtemporal identity (Lowe, 1998, Tallant, 2018). The standard account of change, as the possession of incompatible intrinsic properties at different times, is also unsuitable, for two reasons. First, for the Existence Presentist, the present is metaphysically independent of (B-series) time. Second, a commitment to the thesis of metaphysical change means that the

[5] It is accepted that this is a poor use of language, since 'tense' is a linguistic category. Whenever I refer to 'reality being objectively tensed' I am using shorthand for 'how reality is such that tense reflects something metaphysically fundamental about it'.

whole of what there is, is changing. If the whole of what exists is changing independently of B-series time, then change cannot be defined in terms of B-series time.

In locating an alternative to transtemporal identity as the ground for persistence, I pursue the idea that this needs to be informed by *how* it is that reality is objectively tensed, and therefore arrived at by consideration of the objective correlates of tense. I suggest that the concept of objective passage encompasses two different aspects of reality: *transience* and *continuity* and this indicates an intuitive alignment between persistence and continuity, on the one hand, and real change and transience, on the other.

I proceed to develop suitable accounts of both persistence and change along these lines. I use Lowe's (1998, pp. 110-114) argument that transtemporal identity cannot be grounded without circularity and, on this basis, I adopt a strictly tensed approach to reformulating persistence as 'continuity of existence'. In relation to change, reality appears to exhibit two types of change: substantial and qualitative. Considering examples of both types indicates a fundamental commonality; both involve something new coming into existence, or something existing going out of existence. This leads to a formulation of real (metaphysical) change as 'something coming into existence and/or something going out of existence'. Of relevance here is Deasy's (2017) formulation of presentism in terms of 'transientism'; though, as a formulation of presentism, this account seems to fail (Tallant, 2019, § 2) it embodies an important intuition that the present is transient and continually changing. The proposed reformulation of change aligns change as it applies to an objectively dynamic present with change as it applies to existing entities (entities that are present).

The suggested reformulations of both persistence and real change succeed in *internalising* the dynamic aspects of reality, and formulating them independently of B-series time. They also allow the presentist to positively characterise the nature of the present in response to several critics.[6] As defined,

[6] For example, Williamson (2013, pp. 24-25), Correia and Rosenkranz (2015), Deasy (2017) and Pezet (2017, p. 1835).

real, metaphysical change and persistence are opposing, or orthogonal, features of reality, but it is by encompassing these opposing features that the present exemplifies objective passage, or flow. The present exhibits real, metaphysical change (or transience) in the sense that all that exists comes into existence (in the present) and goes out of existence (in the present), but the present itself also continues on (and so exemplifies persistence). The present is not dynamic by being a movement *in*, or *of*, time; the present is dynamic in virtue of a continuing process of creation and annihilation.

I argue that, as the objective correlates of tense, real change and persistence are metaphysically primitive. Concepts that are metaphysically primitive need to be represented in the categories of an appropriate ontology, and this forms the ground for establishing an ontological framework for presentism that can demonstrate compatibility with physical theory. It is the task of Chapter 6 to develop this framework. I consider the potential for a process ontology to capture the primitive nature of both persistence and real change by reviewing the models of both Seibt (1997) and Rescher (1996). I argue that, as formulated, the category of process, although exemplifying persistence (as continuity through functional recurrence), is unable to reflect real change; change is construed as merely functional variation. Underlying this failure is the fact that real change (as objective creation and annihilation) has an ontological profile that is opposed, or orthogonal, to that of persistence (as continuing existence). I conclude that it is impossible for a single-category ontology to reflect such opposing features of reality.

I note the role played by the interaction of processes in Seibt's (2009) account of emergence, and the scope that this provides for representing real change within a modified process-ontological framework. I make the argument for interaction to be regarded as a separate ontological category from process, one that aligns with the essential features of events. This leads to the formulation of two, mutually-dependent ontological categories (*pure process* and *interaction event*) which reflect the equally primitive nature of persistence and real change. A third ontological category (*concrete substance*) is introduced which sits above the categories of pure process and interaction event. At the fundamental level this substance exists as the quantum field which is characterised by a wave-particle duality. This duality is reflected in the mutual dependence, and equally primitive status, of the categories in the second tier of the ontological hierarchy (*pure process* and *interaction event*). A fourth category, that of *powerful property*, completes the ontological model; powerful properties have a role to play in accounting for causation in a presentist-friendly manner (Chapter 7).

I argue that the proposed model has explanatory worth in accounting for the complex connection between the terms 'process' and 'event' in ordinary language; it also provides a better understanding of the fact that complex entities can both persist and change. However, the principal benefit of the model is that it will be seen to provide a mechanism for achieving the compatibility of presentism with relativistic spacetime.

A notion of existential *boundedness* is introduced, as an additional category feature, to distinguish interaction event from pure process. The notion of boundedness permits an understanding of the origin of duration; the duration of a pure process is the interval that elapses between the interaction event that marks (or bounds) the point at which it comes into existence and the interaction event at which it goes out of existence.

I argue that the categories of the proposed ontological model align, in a functionally relevant manner, with the primitive elements in Belkind's (2012) Primitive Motion Relationism. The latter derives the relativistic spacetime of STR from an axiomatic system under which both uniform, unidirectional motion and the intersection of those motions are primitive. Although Belkind's model is equally compatible with an eternalist ontology (one that also regards spacetime as the structure of reality), a uniquely presentist model is secured through the boundedness of interaction events. In this way Minkowski spacetime is regarded as the structure of an objectively *dynamic* reality, one that exemplifies both real change and persistence.

These arguments support the compatibility of the proposed ontological model for presentism with, at least, the four dimensional spacetime of STR. There is some reason to consider, at least tentatively, that such an ontology might also prove compatible with both GTR and emerging theories of quantum gravity. The need for a new ontology for spacetime is recognised by many commentators[7] as implied by the problems of time within quantum gravity, discussed in Chapter 2. It is suggested that an ontology under which time is derivative of an objectively dynamic reality might present a potential route towards resolving some of these conceptual issues.

One of the principal criticisms levelled against presentism is the difficulty faced in accounting for cross-time relations (CTR), such as spatiotemporal and causal relations. To the extent that relations imply the existence of their relata, the non-existence of both the past and the future suggests that the presentist is unable to provide an obvious ground for such relations. In Chapter 7, I employ the ontological model developed in Chapter 6 to provide an appropriate account of causation to address problematic causal CTR. I suggest that the most suitable approach for the presentist is to adopt a realist, productive account of causation under which causation is not fundamentally a *relation* between entities, at the metaphysical level. This strategy permits the presentist to assert the truth of causal cross-time relational claims in a manner that is not existence-entailing. However, I concede that under the ontology developed in the thesis cross-time spatiotemporal relations remain problematic, and I refer to alternative presentist strategies for dealing with these.

In formulating a productive account of causation, two approaches are available. Those advocating causal dispositionalism (such as Ellis, 2001; Molnar, 2003; Groff, 2008; Mumford and Anjum, 2011; Heil, 2012) see causation as grounded in dispositional properties, construed as real (causally effective) powers to bring about certain effects. Alternatively, causal process theories (e.g. Salmon, 1984, 1994, 1997, and Dowe, 1992, 2000) regard causation as a process of bringing about. The ontology suggested in Chapter 6 ostensibly points towards a process account of causation. However, a critical analysis of causal process theories concludes that the key ontological component, under these models, is that of the *interaction* of processes, and that the notion of causal process is, in

[7] For example, Crowther and Rickles (2014), Smolin (2015), Rovelli (2016), and Butterfield and Isham (2001).

fact, ontologically redundant. This facilitates the formulation of a process-dispositional account of causation which recruits elements from both species of theory and is aligned with the proposed presentist ontology.

In the final chapter (Chapter 8), I consider whether the account of presentism provided might alleviate an additional problem. The asymmetry of fixity[8] that ostensibly obtains between past and future is problematic for the presentist, for whom past and future are unreal. Attempts to ground this asymmetry in either temporal continuing or causation (e.g. Craig, 2001b) risk the charge that the asymmetry of fixity is *presupposed* by any A-theoretic account of temporal continuing or causation (Diekemper, 2005).

I concur with Diekemper that the asymmetry of fixity demands an ontological basis and I follow Craig's (2001b) suggestion that this should be grounded in the nature of objective becoming. I outline an account of objective becoming in line with the proposed ontological model. Objective becoming arises because the present exemplifies the opposing features of real, metaphysical change and persistence. I argue that this gives rise to an asymmetry of ontological *dependence* between past and present, one that does not obtain between the present and the future, and this is the origin of the asymmetry of fixity.

I close with a postscript that revisits the enduring legacy of McTaggart and the relevance of his arguments to the conclusions of this thesis.

[8] The 'asymmetry of fixity' refers to the fact that was has been is fixed, or settled, whilst what has yet to be is open.

CHAPTER 1 - STATIC AND DYNAMIC MODELS OF REALITY

1.1 Introduction

> Frank Ramsey counselled that when a philosophical dispute presents itself as an irresolvable oscillation between two alternatives, the likelihood is that both alternatives are false and share a common false presupposition. (Campbell, 1990, p. xii)

I begin this thesis by reflecting on the historical roots from which the current debates within the philosophy of time arise, and highlight the wider metaphysical paradigms within which the opposing theories of presentism and eternalism reside. I refer to these as the 'static' and 'dynamic' models of reality. The purpose of this excursion is to uncover the source of the problems in reconciling presentism with physical theory.

In section 1.3 I describe how the metaphysical commitments of the static model align well with current physical theory, and in 1.4 I analyse the source of the difficulties for the dynamic theorist in achieving compatibility with those physical theories. In the remainder of the chapter I identify a 'common false presupposition', through an analysis of the approaches to persistence and change within each of the metaphysical models. Though common to both sides of the debate this presupposition particularly obstructs the presentist's endeavours.

1.2 The Static – Dynamic Debate

The polarisation between presentism and eternalism, within the philosophy of time, can be viewed in terms of a wider metaphysical debate concerning the nature of reality, the provenance of which stretches back to (at least) the debates of the pre-Socratic philosophers.

The position that reality exemplifies objective becoming aligns with a view that reality is essentially dynamic, rather than static. This approach sees change as fundamental and objectively real; change is considered part of the furniture of reality, rather than merely an illusion. This view of reality has a long and venerable history which can be traced back to Heraclitus of Ephesus (circa 500

BCE). Heraclitus espoused a philosophy of radical universal flux or dynamic transition and saw change as ubiquitous. Rather than seeing the dynamic nature of reality as a feature which *required explanation,* Heraclitus was the first to suggest that dynamicity stands in 'the role of an explanatory feature' (Seibt, 2018, § 1).

The converse view has an equally long and venerable history. According to Graham (2015), Heraclitus influenced Parmenides of Elea in developing an opposing philosophy based on universal stasis.[9] Parmenides thought that reason and sensation result in contradictory models of reality. To be sure, our sensations provide us with an impression of flux, or constant change, but reason indicates that change is contradictory. His reasoning runs as follows. Parmenides rejected the possibility of reference to 'not-being' since there *is* nothing objectively (in reality) to ground such a reference. Consequently, any account of change ultimately comes down to being able to point to differences between one thing, X, and another thing, Y, and this, in turn, is to state that 'X is not (yet) Y'. Yet we cannot state that 'X is not (yet) Y' since to do so is to refer to the not-being of Y. Therefore, reason supports the view that motion and change are impossible. Assuming that the dictates of reason are elevated over evidence from the senses, we should believe that reality exists as a unified and unchanging whole.

The debate has continued, in various guises, and these two contrasting views of reality have become entrenched within metaphysical discourse, most notably in the philosophy of time. Each side is associated with the adoption of a collection of metaphysical positions that are naturally aligned and underpinned by a common approach to the concept of time. I refer to these metaphysical paradigms as the static and dynamic models of reality respectively.

I employ the term 'static model of reality' to refer to a combination of the following three positions:

[9] A majority of commentators interpret Parmenides' poem to imply a strict monism under which the single entity's being is unchanging and undifferentiated, though others disagree: e.g., Russell interpreted Parmenides as motivated by strictly logical considerations (Palmer, 2016).

1. Eternalism, or the 'block universe' view. This is the view that all times, objects and events are equally actual, or real, and ontologically on a par.[10]

2. The tenseless, or B-theory view of time.[11] This denies the objective reality of tense; all tensed sentences are reducible to a reference to B-relations between objects (namely, 'earlier than', 'later than' and 'simultaneous with').

3. The perdurance view of persistence.[12] Following Lewis (1986a, p. 202) this is the view that 'something perdures iff it persists by having different temporal parts, or stages, at different times, though no part of it is wholly present at more than one time'.

These three, aligned positions together provide a model of reality under which reality is essentially static. It is static in so far as time does not pass or flow. This is because all times are equally real and tense has no objective correlate. There is, therefore, no objective distinction between past, present and future.

In contrast, by 'dynamic model of reality' I refer to the combination of the following positions:

1. A rejection of eternalism; in other words, that it is not the case that there are present, past and future times, objects and events, all of which are

[10] For example, Hales and Johnson (2003) state 'Eternalists are temporal egalitarians, holding that all times are equally real, with no particular time enjoying ontological privilege' (p.528). Similarly, Rea (2003) provides 'Eternalists believe that all past and future objects exist (i.e. there are some past objects, there are some future objects, and there neither were nor will be objects that do not exist)' (p.247). Note, though, that the generalisation of eternalism provided above is not intended to be definitive since it would also encompass those, such as Prior, who believe that times or instants are logical fictions, but who are, nonetheless, not eternalists.
[11] The distinction originates from McTaggart's (1908) argument for the unreality of time where he distinguishes two ways of ordering positions in time. The 'A-Series' orders times and events according to their possession of tensed properties whereas the 'B-Series' orders them according to two-placed relations ('earlier than', 'later than' and 'simultaneous with'). It was Gale (1968) who first coined the terms 'A-theory' and 'B-theory' after McTaggart's distinction between the two series.
[12] Although perdurance is exemplified here by Lewis' renowned definition, since the debate in this area has subsequently shifted I include, under the banner of 'perdurance', positions currently falling under both the term 'perdurance' (which posit temporal parts) and 'exdurance' (which posit temporal stages).

equally actual, or real. This includes presentism (the view that 'only present objects exist'[13]), possibilism (the view that 'the future is still merely possible rather than actual […] the past has become and is fully actual' (Savitt, 2014, § 2.1)), and other dynamic approaches such as McCall's (1994) 'shrinking future' model.

2. An A-theory or tensed view of time. This considers tense a primitive and unanalysable feature of reality. The terms 'past', 'present' and 'future' indicate that reality exemplifies objective passage, or objective becoming.

3. The endurance view of persistence. Something endures 'iff it persists by being wholly present at more than one time' (Lewis, *ibid.*).

These three positions together provide a model of reality that is objectively dynamic. It is dynamic in so far as time passes, or flows, and it is this that underpins objective passage.

In constructing the debate in terms of these contrasting models I do not imply that the adoption of any one of the positions (within a given model) necessitates a commitment to any of the others.[14] The point is rather that, within each model, the positions described are *frequently* held together since they possess a natural alignment with respect to the features that are attributed to time.

1.3 Dominance of the Static Model

The static model of reality, as described, has come to be the dominant position within metaphysics and the philosophy of time. This owes much to the view that it is motivated by science and, in particular, by our current theories of physics.

[13] For example, Markosian (2004). However, as Ingram and Tallant (2018) note the term fails to designate a single, unequivocal view and definitions can vary depending upon whether they range over objects or times. Thus Merricks (2006, p. 103) describes presentism as the view that 'only the present time is real'.

[14] For example, Maudlin (2002) argues that the objective passage of time is compatible with eternalism; similarly, Skow (2009) advocates a version of the 'Moving Spotlight Theory' which combines both a moving present and eternalism. Dorato (2006a) also wishes to claim that the successive occurring of time-like related events is sufficient for a mind-independent and tenseless becoming since he sees it as an *a priori* matter that time-like related events within Minkowski spacetime occur or happen. Mellor (1998) and Simons (2000) both subscribe to a tenseless view of time but deny that this is incompatible with endurantism.

In this section I briefly outline the arguments to support the view that each of the three elements comprising the static model aligns well with current physical theory.

1.3.1 Eternalism

Eternalism entails the ontological parity of all objects, events and times, past, present and future. The argument to eternalism from the relativity of simultaneity within the Special Theory of Relativity (STR) marks the point at which the static model of reality comes to be seen as the dominant metaphysical interpretation of our best physical theories. The original argument was provided by Rietdijk in 1966, followed by Putnam (1967) and subsequently reinforced by Penrose (1990).[15]

The argument is famously criticised by Stein (1968, 1991) who argues that it is reliant for its conclusion on the relativistically incompatible concept of distant present events. This objection is held to be justified by a majority of commentators.[16] Nonetheless, irrespective of the merits of more recent formulations of the argument,[17] it is generally considered that eternalism provides the best (metaphysical) explanation of relativistic kinematic effects, such as time dilation and length contraction.[18] The core of the various arguments is that relativistic kinematic effects provide empirical support for the assertion that spacetime is intrinsically four-dimensional, and the latter can only be explained on the basis of a metaphysical assumption as to the ontological parity of all times and events (i.e. eternalism). An analysis of the arguments involved, and the extent to which physical theories motivate the metaphysical commitments of eternalism, will be discussed in more detail in Chapter 3.

[15] This argument will be discussed in more detail in Chapter 3.
[16] For example, Saunders (2002), Petkov (2006).
[17] Such as provided by Petkov (2006) and Peterson and Silberstein (2010).
[18] See, for example, Balashov and Janssen (2003), Petkov (2006) and Norton (2008).

1.3.2 The B-theory (or tenseless view) of time

The B-theory of time naturally (though not necessarily) aligns with eternalism and similarly gains support from science. As Dieks (2012, p.104) notes:

> In theoretical physics, both classical and relativistic, time is used in the spirit of the B-theory. The four-dimensional Minkowski diagrams of special relativity are typical: they represent (parts of) the history of the universe, extended both in time and space, by specifying all events at their dates and locations, together with their spatial and temporal interrelations. The important point is that there is no preferred Now in these diagrams, let alone a flowing Now.

The B-theory, as a model of time, is supported by physics in that it suffices to explain all physical phenomena. Physics has no explanatory requirement for tense, or for a privileged present, in its modelling of reality. On the basis of Ockham's razor, there is no naturalistic reason to posit an objective, privileged present.

1.3.3 Perdurantism

The third element within the static model of reality is a perdurance account of persistence. I discuss the compatibility of both endurance and perdurance with presentism, in greater detail, within Chapter 5. The purpose here is to outline how perdurance supports the compatibility of the static model with physical theory.

Perdurance aims to address the problem of persistence through change. This arises from a conflict between change, viewed as the possession of incompatible properties by objects at different times, and Leibniz's Law.[19] Under Leibniz's Law, the preservation of numerical identity between A at t_1 and A at t_2 requires both entities to have all their properties in common. Yet for an entity, A, where it is the case that 'A is red (all over)', at one time, and 'A is blue (all over)', at

[19] Leibniz's Law of Identity states that A is identical with B *iff* every property of A is a property of B and vice versa. This is similar to, but distinct from, the 'Principle of the Identity of Indiscernibles': A and B are absolutely indiscernible, *iff* they are identical.

some other time, this is clearly not the case. Since being red (all over) and being blue (all over) are incompatible properties a contradiction ensues. The preferred solution to this (e.g. Lewis, 1986a) is provided by the perdurance model of persistence. Persistence and change are reconciled by positing temporal parts (e.g., A-at-t_1) as the basic existents, where different temporal parts bear the relevant incompatible properties. Since the incompatible properties are possessed by different entities (the temporal parts), conflict with Leibniz's Law is circumvented. Persistence is also accommodated; persistence is only attributable to the whole entity, which is seen as the mereological sum of its temporal parts.

The perdurance view of persistence and the concept of temporal parts also gain support from the STR. The relativity of simultaneity within the STR implies there is no objective fact of the matter as to whether two events happen simultaneously, or whether one occurs before the other: what an observer judges will depend on the reference frame adopted. The corollary of this is that there is no absolute division of spacetime into three spatial and one uniquely temporal dimension. Instead, within the spacetime of the STR ('Minkowski spacetime'), spatial and temporal dimensions are entangled into a unified four-dimensional manifold; objects thereby exist as four-dimensional entities. There are therefore multiple ways of dividing four-dimensional objects into separate three-dimensional temporal parts. This aligns with the perdurance model of persistence under which an object persists as a four-dimensional whole of temporal parts, none of which is unique or ontologically privileged.

In conclusion, each of the different positions characterising the static model of reality gains support from science. In addition, the coherence and consistency of the separate elements of the model provide good reason for its continued dominance.

1.4 The Problems Encountered by the Dynamic Model

Proponents of the dynamic model commit to a tensed view of time. This is associated with the belief that tense reflects a fundamental truth about reality, namely that reality exemplifies objective passage. However, serious problems arise in explaining the nature of this.

There are two main ways in which objective passage might be understood. First, by the idea that time itself passes; there is an objective temporal flow which governs the transition of reality between that which has yet to exist and that which has existed. The alternative option is to assert that events or objects move through time by successively possessing transitory tensed properties (pastness, presentness and futurity). Both these approaches suffer problems arising from McTaggart's (1908) argument. The notion of temporal flow faces additional issues in relation to coherence, and its incompatibility with relativistic physics. It is these three problems that will now be discussed.

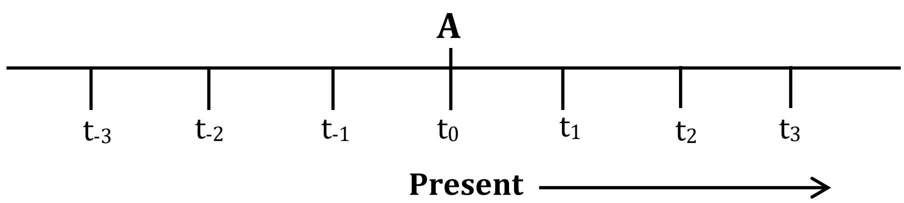
1.4.1 McTaggart-Style Problems – Passage as the acquisition of temporal properties

McTaggart famously argued for the unreality of time on the basis of an analysis of the concept of time. He highlighted the fact that this concept includes two distinct elements, which he referred to as the 'A-series' and the 'B-series', and noted that 'we never *observe* time except as forming both these series' (1908, p. 458). These two series serve to order the positions of events occurring in time in two distinct ways. Under the A-series, events are ordered in terms of whether they are past, present or future; further, all events eventually move successively along this series. Events can also be ordered in terms of the B-series: this positions events in terms of whether they are earlier than, later than, or simultaneous with other events. Whereas the position of an event in the A-series is continually changing, the position of the same event in the B-series is forever fixed and permanent.

The overall form of McTaggart's argument is first to argue that without change there would be no time and second, that change requires the A-series. Since the A-series is, in his eyes, incoherent it follows that time cannot exist. For McTaggart there must be more to (real) change than simply having incompatible properties at different times. Under the B-series change is simply the possession by an object of different properties at different temporal locations; however, since all these locations co-exist this cannot be 'real' change, as this is no different from spatial variation. Real change therefore requires there to be changing facts about how things are *now* and so requires that the *present time* keeps changing; in other words, that there is a flow of time, or passage. The B-series therefore needs to be supplemented with the A-series in order to represent real change. So, for McTaggart, real change requires time to flow. As is well known, McTaggart subsequently argues that the notion of time flowing leads to contradiction; for McTaggart, if time cannot flow, there can be no change in reality and therefore time is unreal.

Any account of objective passage formulated in terms of transitory tensed properties also falls foul of McTaggart's argument and engenders a vicious infinite regress. Pastness, presentness and futurity are incompatible properties: if an object or event is past, it cannot also be present. Yet these properties must be possessed by all events which move from the future, into the present and from then to the past, so a contradiction ensues. The A-theorist might object that these are held successively, not simultaneously, and introduce second-order tensed predicates to indicate this (Dainton, 2010). This means that for a given present event (A) at present time (t_0):

'Event A is present in the present (t_0), past in the future (t_3) and future in the past (t_{-3})'



There is no incompatibility here, argues the A-theorist. However, though this is true of the present time (t_0), the problem is that event A doesn't *stay* in the present: it is continually moving and changing its tensed status. So there will always be times for which we can assert a conjunction such as:

Event A is past in the present (t_3), present in the present (t_0) and future in the present (t_{-3})

This *is* contradictory. Further, introducing second-order or even infinitely higher order tensed properties fails to eliminate the paradox of incompatible properties. It is generally felt that, despite its shortcomings, McTaggart's argument succeeds against any dynamic theory of time underpinned by either transitory or intrinsic tensed properties.[20]

1.4.2 The Coherence of Temporal Flow

There are also intractable problems associated with conceiving the flow, or passage, of time in terms of some form of motion. Arguments have been provided by several commentators[21] but most famously by J.J.C. Smart (1949) who draws the analogy with a 'flowing river'. Any notion of time's flowing given in terms of motion requires reference to a second temporal dimension or meta-time, since all motion is defined in terms of a rate with respect to time. Yet the posited meta-time, if truly temporal, must similarly flow or pass, and this kick-starts an infinite regress of meta-times. On the other hand, employing a *static* background meta-time also fails (Dainton, 2010), since each moment of ordinary time (permanently) possesses presentness, albeit at different meta-times. Consequently, any sense of a unique and flowing present is lost.

Price (2011) objects that the notion of temporal flow is actually incoherent, since its coherence would require us to be able to state at what *rate* time passes. In response, Maudlin considers it '*a priori* that if time passes at all, it passes at one second per second' (2007, p. 112). Price counters that this is no more informative than saying that a journey from Sydney to Melbourne passes at a rate of one mile per mile.

For van Inwagen (2002, p. 59) the real issue in formulating the passage of time using Maudlin's rate (of one second per second) is that this does not provide a rate of *change*; dividing one second by one second just gives one, and unity cannot be a rate of change. Olson (2009) also views Maudlin's suggestion as odd since all other changes can conceivably occur at different rates. We cannot

[20] There is an extensive literature on this and only cursory reference is made here. Dainton (2010), for example, provides a review of the problems associated with transitory tensed properties.
[21] Such as Dorato (2002), Olson (2009), Price (2011).

measure the rate of time's passage using a clock since clocks measure the amount of time (i.e., the interval) between any two events. As Olson notes, in order to measure the rate of time's passage we should need a 'chronological instrument analogous to a speedometer' and concludes that 'time's passage would have to be radically different from any other sort of change' (2009, p.447). So the present cannot be 'moving' or 'changing' in any standard meaning of the terms, nor can we be moving in time.

In defence of passage, Markosian (1993) argues against the requirement for a meta-time with respect to which time passes; for him, time passes but not at any *rate*. Those who assume that the passage of time requires a rate at which it passes make a 'category mistake' since:

> the answer would have to involve a comparison between the pure passage of time and the pure passage of time, but such an answer would not make sense because the pure passage of time has a unique status among changes – it is the one to which other, normal changes are to be compared. (Markosian, 1993, p.843)

A last-ditch option, for the dynamic theorist, as Zinkernagel (2011) notes, is simply to hold that the passage of time is primitive and unanalysable.

In summary, in asserting that reality exemplifies objective passage one option open to the dynamic theorist is to underpin this with the passing of time itself. This section has summarised the main difficulties encountered in formulating a sufficiently rigorous notion of temporal flow upon which to base such accounts.

1.4.3 Incompatibility with Relativity Theory – the Need for Absolute Simultaneity[22]

A third problem faced by the dynamic theorist is incompatibility with relativity theory. Dynamic theorists, of whatever species, share a commitment to the

[22] 'Absolute simultaneity' means that the temporal interval between two events, so related, is zero, in all frames of reference. This is denied by the STR.

rejection of the ontological parity of all times, objects and events (i.e. a rejection of eternalism). In particular, the present is considered ontologically privileged.

A widely held assumption is that the present is privileged in the sense that it represents a unique, global time.[23] In the arena of spacetime theories, this assumption, in turn, requires an absolute, or universal, simultaneity. Objective passage would thereby require the movement, or flow, of this privileged global time. The notion that the dynamic theorist must be committed to absolute simultaneity goes back to Gödel, who used this to argue against the reality of time. As Zinkernagel (2011) describes:

> Gödel effectively argued that time is real only if change is real, and that change is real only if there is an objective and universal lapse (or flow) of time. Moreover, Gödel took such an objective lapse to be equivalent to the fact "that reality consists of an infinity of layers of `now' which come into existence successively" (Gödel 1949, 558); and this picture of reality is only possible, according to Gödel, if a distinguished global time can be found. (p.13)

This presents the most significant problem for any dynamic theory aiming to be compatible with physical theory. Within the relativistic spacetime of the STR the ontologically privileged status of the present can no longer be identified with a unique global time. There are no unique hyperplanes of simultaneity and there is no frame-independent notion of absolute simultaneity.

[23] For example, Craig (2008), in championing the 'Lorentzian' interpretation of STR assumes that absolute simultaneity is required by any theory accepting the reality of tense and objective becoming. Nasmith (2011) assumes 'the validity of presentism is tied to the existence of the absolute simultaneity relation' (§ 2.2). Hawley (2006, p. 451) remarks: 'Presentists claim that only what is present exists, which is to say only those events simultaneous with now exist'. Similarly, Saunders (2002, p. 3): 'According to presentism, all that is physically real is the present – a system of physical events all of which are simultaneous with each other', Monton (2006, p. 2): 'The presentist […], believes that the universe is three-dimensional' and Zimmerman (2011, p. 166): 'If, as A-theorists believe, there is an objective fact about what is presently happening, there must be an objective fact about which events are simultaneous with one another'.

The dynamic theorist who wishes to identify the present with either a privileged frame of reference[24] or a universal hyperplane of simultaneity either needs to reject outright the key principles of the STR (this might be justified, for example, on the grounds that the STR represents incomplete physics) or look to other empirically equivalent theories that permit a privileged reference frame (for example, quantum mechanics and general relativity both permit this). I provide an overview of these attempts in what follows.

Despite its incompatibility with the spacetime of STR, relativistic physics does not, as such, prohibit the possibility of absolute simultaneity. Given this, Tooley's (1997) approach is to develop a comprehensive and systematic reworking of the Special Theory of Relativity under which absolute simultaneity can be provided for. Similarly, within the General Theory of Relativity (GTR) certain solutions to Einstein's Field Equations (such as the Friedmann-Robertson-Walker model) permit the partitioning of the universe into preferred divisions (or 'foliations') of three-dimensional spatial surfaces that allow for a global time (or absolute simultaneity) to apply to all events on such a surface. This fact has facilitated strategies which define an absolute cosmic time with reference to the expansion of the universe. Bourne (2004) provides an overview of these approaches but finds them wanting. The notion of cosmic time is both epistemologically and phenomenologically inaccessible to individuals, and so is unlikely to connect with either our concepts of, or our experience of, simultaneity and temporal passage. More importantly, since the expansion of the universe is a contingent matter it renders objective temporal passage equally contingent. Bourne questions whether it is 'plausible that the metaphysical notion of temporal becoming can be equated with a physical process that is contingent on the particular distribution of matter in the universe' (2004, p. 116). Such a contingent relation appears unable to hit the 'metaphysical mark'; why should expansion of the universe (and so the distribution of its matter) have anything to do with the nature of time *per se*?

[24] A 'frame of reference' is a coordinate system centred on a given point in spacetime and assumed to be at rest; a 'privileged' frame is one permitting a definition of absolute simultaneity.

> although it defines what it is for events to be simultaneous […], it says nothing about what it is for us to be located in the present, […] and it doesn't explain our belief that the past is fixed and the future is open. (*ibid* p.117)

Alternative strategies look for support from quantum mechanics, in particular, an experimentally verified feature of quantum reality known as 'non-locality'. Particles, such as electrons, can be prepared to be in a certain ('entangled') state such that their measurement variables (e.g., spin) act in a correlated manner across vast spatial distances. The particles violate locality since they act as though there were no distance between them. The argument proceeds as follows: if the measurement of one particle instantaneously 'affects' the outcome of the measurement of the other particle (regardless of spatial separation), then the particles must act simultaneously. And simultaneity across, in theory, an infinite spatial separation implies the existence of an absolute, or universal time.

Callender (2008) assesses the claims[25] that quantum non-locality requires absolute simultaneity, and thereby supports a preferred foliation of spacetime into separate spatial and temporal dimensions. He notes that it was Popper (1982) who first suggested that the correlations, indicated in the EPR[26] experiments (as described in Bell, 1987), suggested action-at-a-distance and thus the existence of absolute space. However, this interpretation of quantum non-locality is not clear cut, since it depends upon assumptions regarding both causality[27] and the correct interpretation given to the concept of measurement within quantum theory.

Looking further forward, Monton (2006) considers that developing theories of quantum gravity might potentially provide a privileged reference frame but,

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[25] For example, those argued for by Popper (1982) and Lucas (1998). Maudlin (1994) also discusses the morals to be drawn from this.

[26] The EPR paradox (after Einstein, Podolsky and Rosen, 1935) is a thought experiment which aims to reveal an inherent paradox in quantum theory such that either quantum theory provides an incomplete description of reality or action is non-local.

[27] For example, is it actually the case that measurement of one particle *causally affects* the other?

given that these theories are still very much under development, the metaphysical implications are difficult to ascertain.

Even so, the main problem with all these approaches is that even if it were possible to identify a unique plane of simultaneity (within a future, unified physical theory) a fatal blow to such accounts is dealt by Callender's (2008) 'coordination problem'. The argument here is that there is no way of knowing that the physically preferred foliation of spacetime dictated by that theory coincides with the *metaphysically* preferred foliation of objective passage. The dynamic theorist still needs to offer additional arguments to support the preferred ontological status of the foliation designated as 'the present', as well as some form of dynamic process of generation and annihilation. This criticism is brutally general and can be targeted at any physically preferred foliation and is, he suggests, 'in principle irresolvable' (2008, p.63). It does indeed seem difficult to see how this might be overcome.

As Callender is at pains to point out, there is no physical relevance to the notion of absolute simultaneity (viz. two events objectively happening at the same time); physics just has no requirement for this notion. Callender himself considers that the best route available to the dynamic theorist, in responding to the argument to eternalism from the relativity of simultaneity, is to adopt a Lorentzian interpretation of the STR with its 3+1 spacetime ontology (also supported by Craig, 2008). This permits absolute simultaneity as an invariant feature of the spacetime. The downside to this approach is that it requires positing additional structure (viz. the ether) that is, in principle, unobservable. Positing additional, unobservable entities goes against the principle of parsimony (Ockham's Razor): the methodological principle which favours simplicity as the criterion of choice amongst competing scientific theories. This might therefore be considered an ontological extravagance too far.

1.4.4 A Compatible Account of Objective Passage?

Given the difficulties associated with the notion of absolute simultaneity, this section will consider the two main approaches to objective passage that appear compatible with relativistic spacetime. I argue that each incurs problems which makes it unsuitable for the dynamic theorist to pursue.

1.4.4.1 *A Relativistic Relation of Becoming - Stein (1991) and Bigaj (2008)*

Stein (1991, p.148), in a famous response to the Rietdijk-Putnam argument (§1.3.1), proposes a model of objective becoming in terms of a two-place relation, *R,* between spacetime points within Minkowski spacetime. *R* is a relation of 'already definite' or 'having become' such that *Rab* provides that 'spacetime point *a* is definite with respect to *b*'. This relation is both transitive and reflexive and has the condition that 'for any point *a* there is a point *b* such that ¬*Rab'*. So, for any spacetime point *a* there is a point *b* that is not already definite with respect to it. The relation only applies between a point *a* and any point in or on *a's* past light cone[28] in the Minkowski spacetime diagram. Equivalently, *Rab* iff *b* lies in the causal past of *a.* The relation, *R,* thereby represents, for Stein, a notion of becoming that is Lorentz-invariant,[29] and so compatible with relativistic spacetime, yet one that permits a division between a definite past and an open future.

Several commentators[30] agree that Stein has shown that objective becoming is not *ruled out* as a possibility by the Rietdijk-Putnam argument to eternalism, and that the latter only succeeds against dynamic models of time that require a universe-wide spatially extended present. However, the principal criticism against Stein's argument is that its success means that it unacceptably relativizes reality to a single spacetime point, the 'here-now'; there is no longer a universe-wide becoming. Stein's model does not permit there to be an extended present and this follows from the transitivity of the *R* relation. If a given spacetime point, *a*, were *R* related ('definite with respect to') to another point, *b*, (where *b* is neither *a* itself nor a point in *a*'s causal past) then the

[28] The 'past light cone' for any spacetime point, *a*, is that portion of spacetime containing points (and potential events) that can be causally related to *a*. It is bounded by a light cone since the velocity of light, *c*, represents an upper limit to the transmission of causal influence.
[29] By 'Lorentz-invariant' I mean that the notion of becoming would be agreed upon by all observers moving at constant relative velocities. In general, Lorentz-invariance expresses the notion that the laws of physics are the same in all inertial reference frames.
[30] For example, Dorato (1995, Ch. 11), Clifton and Hogarth (1995) and Tooley (1997, p. 337).

transitivity of R would have the result that a is definite with respect to *all* other spacetime points. Unless R is restricted to hold only between either a, or points in the causal past of a, the conclusion of eternalism follows: all events are definite with respect to one other.

Petkov (2006, p. 212) refers to this implication of Stein's model as 'event solipsism – for every observer the world would be reduced to a single event (the event 'here-now')'. Under such a 'point presentism' reality is reduced to a single (and therefore zero-dimensional) point, yet the universe, according to science, exhibits four-dimensionality. This, Petkov argues, entails that such presentism is unable to account for length contraction and time dilation, phenomena for which we have plenty of empirical evidence.[31] Stein's notion of becoming is described by Dorato (1995) as 'an uncorrelated, non-denumerable set of narrow creeks' (p.184), rather than a universal 'tide' of becoming. There is no one privileged perspective on reality, rather, numerous equivalent points for which certain things are real. Here we might concur with Callender (2000) that the minimum acceptable construal of *objective* becoming surely requires that the present of any given event contains at least one other event (the 'non-uniqueness condition').

Stein's model was subsequently supplemented by Bigaj (2008) to include a complementary relation, S, of 'indefiniteness'[32] which provides for an 'open sphere of future possibilities' (p. 231). For Bigaj, any complete notion of becoming requires *both* a determinate set of things that have already come to be and an indeterminate set of things that have yet to become, or, future possibilities. Bigaj considers his method provides a more 'dynamic' model than Stein's since it provides for a cumulative becoming along a given world-line (rather than a single spacetime point). Nonetheless the principal objection remains that the model localises the present to the world-line of a single object, and so unacceptably relativizes reality.

[31] Petkov's arguments are analysed in detail within Chapter 3.

[32] Where $Sab \equiv$ 'the state at b is indefinite (open, unsettled) as of a' (Bigaj, 2008, p. 231).

1.4.4.2 *Becoming as the Successive 'Happening' of Events*

Here I briefly describe the second approach to objective becoming available within the confines of relativistic spacetime. However, this approach is not one that is open to the dynamic theorist since it is predicated on an eternalist theory of time.

Dorato (2002, 2006a) and Dieks (2006) reject the idea that objective becoming requires a successive coming into existence of global nows (or indeed any notion of a moving now). Instead, they consider that a concept of mind-independent and tenseless becoming is available if becoming is construed simply as the successive 'happening' of events in spacetime. For Dorato it is an *a priori* matter that events within Minkowski spacetime 'occur' or 'happen'. Because of this the eternalist is not committed to a position where all events are simultaneous since events occur in temporal succession. So, although all actual events (past, present and future) exist ontologically on a par, at their respective spatiotemporal locations, their *existence at those locations* is sufficient for objective becoming. As a consequence, becoming does not involve any ontological asymmetry: it does not provide for an open future or, indeed, any ontological distinction between past, present and future. Becoming reduces to, essentially, a structural feature of spacetime.

Although the approach avoids the solipsism of Stein's 'here-now' model, it denies the present a privileged ontological status and, for this reason, is an unsuitable mechanism for a compatibilist approach to presentism. Maudlin (2007, p. 116) and Price (2011) also object to the localised approach that is common to both the Stein and Dorato models, since it fails to ground an objective, non-contingent distinction between past and future.

1.4.5 Summary of Issues Presented by the Dynamic Model

The dynamic theorist faces a challenge in explicating objective passage and thereby accounting for the fact that tense reflects an objective feature of reality. Accounts that rely upon either the positing of transitory tensed properties or the concept of temporal flow face intractable problems. Both approaches are susceptible to McTaggart-style problems. In addition, establishing a *compatibilist* account of objective passage faces the further difficulty of locating a unique and universal plane of simultaneity, with respect to which the universe can be said to evolve in time. If the pursuit of absolute simultaneity is abandoned the only alternative appears to be to model objective passage within the arena of four-dimensional spacetime. Although Stein shows this can be achieved, it unacceptably relativizes reality to a single spacetime point.

It appears, therefore, that the theorist who aims for an account compatible with physical theory is wedged between a rock and a hard place: either accept the conclusion of eternalism (and ontological parity) or relativize existence to a single reference frame. This binary viewpoint is one that is frequently encountered within the literature.[33] Conversely, a dynamic theorist who rejects the STR and looks to alternative physical theories to provide a notion of absolute simultaneity will still fall foul of Callender's (2008) coordination problem.

1.5 A 'Common False Presupposition'?

The first half of this chapter highlights that the current debate between presentism and eternalism can be viewed within the wider context: that of an historical debate between alternative, metaphysical views of reality. Within one camp reality is regarded as fundamentally static, while the other sees it as essentially dynamic. Each of these views of reality is underpinned by a corresponding view of time. Reality is dynamic in so far as time is dynamic; whereas a static reality is grounded in a static view of time.

In the following section I argue that, although the concept of time has disparate *features* under each of the models of reality described, within both it plays a similar, and metaphysically fundamental, role. This is brought out by considering the role played by time in the accounts of change and persistence under each model, and it is for this reason that the debate between presentism

[33] For example, Nasmith (2011, § 2.1) notes that the arguments to eternalism attempt to reduce the presentist position to 'absurdity' by 'compelling the presentist to either reject presentism or accept that the existence of distant reality is observer dependent'. Saunders (2002) similarly notes the dilemma: for the presentist committed to absolute simultaneity, there are only two compatible relations (R) definable within STR. One leads to the result that all events are real; the other to the conclusion that only one (the 'here-now') event is real.

and eternalism needs to be considered within the wider metaphysical context. I argue that the role played by time is underpinned by a 'common false presupposition' (hence the quotation from Campbell (1990) at the head of this chapter). The presupposition at work is that time is prior to, or metaphysically independent from, the existence of entities. I subsequently argue that it is this shared presupposition that severely obstructs attempts to formulate a compatibilist account of presentism.

1.5.1 The Role of Time within the Opposing Metaphysical Models

1.5.1.1 *The Static Model*

The tenseless view of time denies that tense indicates any metaphysically fundamental feature of reality. Any *sense* that time passes can be explained in terms of human perception of the world and any *talk of*, or reference to, time passing can be reduced to B-relations[34] in a token-reflexive manner. Since the B-series relations are permanent and unchanging this implies that time is essentially static. As such it forms a static background compatible with the four-dimensional manifold of Minkowski spacetime. This manifold specifies the spatial and temporal relations existing between all objects and events that reside at their respective locations on the manifold. The manifold of tenseless time also serves to underpin the models of both persistence and change under the static model.

Change is standardly defined in terms of incompatible properties at different times. For persisting object, A, and incompatible properties, F and G, a temporal change in A is given by:

A (temporally) changes[35] $=_{\text{def}}$ A is F at t_1 and A is G at t_2.

Under perdurance entities persist by having different temporal parts, or stages, at different times. As noted above, any potential conflict with Leibniz's Law is circumvented by temporally indexing the subject term so that the incompatible

[34] I.e., the relations of being earlier than, of being later than, and of being simultaneous with.
[35] From here on, the term 'change' is used (unless otherwise indicated) to mean solely temporal change, rather than, for example, spatial change or Cambridge change or other forms of variation.

predicates are true of different entities: the different temporal parts. If the different temporal parts are signified by 'A-at-t_1', 'A-at-t_2', and so on, change is formulated under the static model (SM) as follows:

(i.i) A changes (SM) $=_{def}$ A-at-t_1 is F and A-at-t_2 is G

This means, though, that the different temporal parts are themselves unchanging.

Persistence, as perdurance, is given as the sum of these temporal parts.

(i.ii) A persists (SM) from t_1-t_n $=_{def}$ at each time t_x, in the interval t_1-t_n, there exists a temporal part of A, A-at-t_x

Claims about identity over time (persistence) apply only to the four-dimensional whole, namely, the mereological sum of the individual temporal parts.

To conclude: the manifold of tenseless time within the static model provides the background with respect to which objects both persist and change; persistence and change are both *defined in terms of* time.

1.5.1.2 *The Dynamic Model*

In contrast to the unchanging background of the static model, time objectively passes under the dynamic model: time is essentially dynamic and continually changing. Although time has this very different nature, it also functions as an external background, with respect to which objects both persist and change. As a *dynamic* background time is continually changing or moving forward and in doing so it functions to lend reality a dynamic aspect.

Under the dynamic model (DM) change is also defined, in the standard manner, by reference to property incompatibility at different times, though the endurantist employs an alternative mechanism to avoid the difficulties presented by Leibniz's Law. The solution here is to employ a temporal indexation of the incompatible properties in one of several ways. Seibt (1997, p. 153) distinguishes five methods that endurantist accounts use to model change:

(ii.i) A changes (DM) = $_{def}$:

A is F-at-t_1 and A is G-at-t_2 *or,*

A is-at-t_1 F and A is-at-t_2 G *or,*

at t_1: A is F and at t_2: A is G *or,*

F(A, t_1) and G (A, t_2) *or,*

A ((is F) at t_1) and A ((is G) at t_2)

In terms of persistence, under endurance the whole entity (A) persists by moving through time. Time, as a dynamic background, provides for the persistence of objects:

(ii.ii) A persists (DM) from t_1-t_n = $_{def}$ at each time t_x, in the interval t_1-t_n, there exists an object A

To conclude, though time possesses very different features under the dynamic model nonetheless it provides the background with respect to which objects both persist and change. As is the case under the static model, persistence and change are both defined with reference to separate temporal instants.

1.5.2 The Metaphysical Status of Time Under the Static and Dynamic Models

I argue above that within both opposing metaphysical paradigms there is a conceptual dependence of both persistence and change on time: persistence is persistence over time and change occurs in time. This does not, in itself, permit conclusions to be drawn as to the relations of metaphysical dependence between time, persistence and change. In what follows I suggest that there is an implicit assumption at work, common to both models, and this is the assumption that time is substantival: it is external to, and independent from, the existence of entities. Entities exist *in* time or *at* a time. This leads onto the further assumption that both change and persistence are metaphysically dependent on, or derivative of, substantival time. I argue that it is this metaphysical assumption that hinders presentist attempts at formulating a model compatible with physical theory.

Hawley (2020, § 2) makes the following observation:

> In the past few years […] some have suggested that debates about persistence are better understood as debates about location – how are material objects located in (or extended through) time, and how does this compare with the way(s) in which material objects are located in (or extended through) space?

This notion of *location in* time, or *existence-at* a time is also brought out in the exemplary definition of persistence from Lewis (1986a, p. 202):

> Let us say that something *persists* iff, somehow or other, it exists at various times; this is the neutral word: Something *perdures* iff it persists by having different temporal parts, or stages, at different times […] whereas it *endures* iff it persists by being wholly present at more than one time.

The terminology of locations is employed by both sides in the perdurance-endurance debate and, as Parsons (2007) notes, the locative explication of persistence as 'existing at' various times brings with it a 'prima facie ontological commitment' to substantivalism. I propose, in what follows, that the assumption that times are substantival and locative fits more naturally with both endurance and perdurance than does a relationist model of time.

As previously noted, under endurance property instantiation is indexed to times. Under a substantival account the indexing of properties is easily understood. A given property, *F*, occurs, or is located *at*, the relevant instant, and a different, incompatible property is located, or occurs, *at* a separate instant of substantival time. In other words, there is some *thing*, an independently existing, substantival time, to which different properties are indexed. As Hawthorne and Sider (2002, p.68) suggest 'this talk of instantiation at times presupposes the existence of times'. This is not so intuitive in the case of a relationist model of time. Under a relationist model there are no independently existing, substantial times, there are just propertied enduring entities and certain, primitive relations that exist between them, relations such as *simultaneous with* and *being n units after*.

Sider (2001) maintains that endurance cannot work satisfactorily under a relationalist model, and the situation where enduring objects temporally overlap is particularly complicated. Sider (p.114) describes an example where he creates and then destroys a statue; in this case, the period of time that the statue persists through partially overlaps his own time span. Where an external (and so, substantival) time is posited, the period during which Sider and the statue co-exist (and so temporally overlap) can be modelled by reference to a fixed time span in substantival time. Unless there is this external (substantival) time, *within which* both Sider and the statue can be said to co-exist (and temporally overlap), it is difficult to see exactly what else might constitute the required relation between two, wholly existing, entities. Sider suggests the best option for the endurantist is to resort to a complex conjunction of relational facts. For example, assume Sider to be represented by object, x, instantiating property, F, over an interval t_0 to t_3, and the statue he creates is object, y, that exists between t_1 and t_2, and instantiates property, G throughout. A relationist model of endurance might describe the situation as follows:

> x *is* F *one unit after* x *is* F (informally, this holds in virtue of t_0 and t_1, for example, as well as t_1 and t_2, and t_2 and t_3); x *is* F *two units after* x *is* F (in virtue of t_0 and t_2, or t_1 and t_3); x *is* F *three units after* x *is* F; y *is* G *one unit after* y *is* G; y *is* G *one unit after* x *is* F (in virtue of e.g. *x* at t0 and y at t1); y *is* G *two units after* x *is* F; x *is* F *one unit after* y *is* G (in virtue of e.g. x at t2 and y at t1); and so on; *it is not the case that* x *is* F *four units after* x *is* F; and so on. (2001, p.115)

Nonetheless, Sider views this approach as ultimately unsatisfactory since certain, distinct possibilities cannot be distinguished, such as that of an unchanging object in an infinite linear time, and the same object persisting in circular time.

There are further objections to a relationist model of endurance. Rendering an object's properties (such as shape) relative to other *objects* in the universe, rather than relative to (external) times, appears 'objectionably relational' (p.117) according to Sider. This echoes an objection from Lewis: contrary to intuition it appears that 'nothing just has a shape *simpliciter*' (Lewis, 1988, p.65). This objection could be mitigated by relating an object's property to its own properties at other times (for example, *being cold one unit after one is hot*); however, if this line is taken it is then not possible to specify temporal facts relating *different* objects:

> Given only sentences like 'x is hot n units after x is hot' and 'y is hot m units after y is hot', one cannot specify which of x or y is hot first, or whether they are hot at the same time. (Sider, 2001, p.118)

The endurance model of persistence seems more naturally explicated under a substantival model of time: objects persist by moving through an external, substantial time, and they change in so far as incompatible properties are located at different instants of that external time. Perdurance is also more appropriately modelled on the assumption of a substantival time.

Under perdurance an object persists by possessing different temporal parts at different times, and essential to the nature of a temporal part is that, *qua* temporal, it involves existence *at* a particular time. Temporal parts are more explicitly temporally locative than enduring entities. As Parsons (2007, p.215) explains, perdurance involves a three-place relation: 'a relation between an object, a time, and its temporal part *at that time*'. On the principle that relations imply the existence of their relata, this, at first glance, seems to suggest the separate existence of both times and temporal parts.

However, this is too hasty. The temporal parts theorist might also pursue a relational model in a manner analogous to the endurantist. As such, temporal parts could stand in primitive relations of *being simultaneous with*, *being after* and *being before*. For example, temporal part x-at-t_3 bears a primitive *two units after* relation to temporal part x-at-t_1. In fact, under perdurance, a relational model is made slightly easier. The temporal parts theorist is better able to accommodate the situation of temporally overlapping objects (such as in the example of Sider and his statue). Here, temporal overlapping is described by a relation of simultaneity between each temporal part of the statue and the corresponding temporal parts of Sider. Nonetheless, Sider's objection against a relationist model of endurantism carries across to a relationist perdurantism. The temporal parts theorist is similarly unable to distinguish an unchanging object in an infinite linear time from the same object in circular time.

Attempts to account for both endurance and perdurance under a relational model of time encounter problems that do not occur under an assumption of substantivalism, and this appears to arise from the locative explication of persistence which is common to each side in the debate. This suggestion is reinforced by Parsons (2007) who attempts to provide a mutually acceptable, logical framework for the debate between perdurance and endurance. Parsons offers a theory of location that aims to prevent both sides from talking at cross-purposes. However, in doing so, he concludes that formulating a relationist theory of location (irrespective of the model of persistence adopted) 'would be a difficult task' (p.226). The locative nature of persistence, as existence *through* time, or *in* time, appears to require a substantival notion of time.

In a similar vein, Hawthorne and Sider (2002) argue that models under which locations are *not* reified (i.e. by adopting a relationist rather than substantival approach to spacetime locations) exclude certain possibilities, unless metaphysically unacceptable notions are employed. For example, the relationist cannot distinguish between the following two scenarios:

> […] in one world a certain light comes into existence at some time, and flashes red and blue every minute forever after, whereas in a second world it has existed forever and will continue to exist forever, flashing red and blue as before. (p.73)

The first world could be described in relationist-friendly terms by using statements such as 'the light is red one minute before it is blue, then is red one minute after that, then blue one minute after that' etc. However, this is insufficient to distinguish it from the second world unless an 'infinitary sentence' is used, for example, '... the light is red one minute after that, then blue one minute after that, then red one minute after that, then blue one minute after that…' (p.74). Hawthorne and Sider maintain that it is not possible for such sentences to be reduced to finite sentences, and they deem 'infinitary sentences' to be metaphysically unacceptable. This argument seems equally valid for both perdurance and endurance.

Although it is clearly possible to conceptualise times as existing without being committed to a substantival time (or times), both models of persistence, endurance and perdurance, sit more easily and naturally with a substantivalist model of time: persistence is the existence of an entity *through* time or *in* time. The substantival-relational debate (which concerns the nature of time) is inconsequential in relation to the debate between the endurantist and perdurantist over the nature of persistence. Given this, I suggest that if both models of persistence sit more *naturally* within the arena of a substantival time then it seems likely that this would remain an unquestioned assumption on both sides. There would be no reason to question an assumption that has no material effect on the debate. Nonetheless, there are two metaphysical implications that follow from such an assumption, and I argue in the following section that it is one of these, in particular, that is the source of the problems encountered by the dynamic theorist.

The first implication is this: if persistence is existence through, or in, substantival time, this implies that persistence is metaphysically derivative of time. In the absence of (substantival) time there would be no persistence, and no persisting entities.

Second, as has been noted, each theory of persistence also engenders a corresponding account of change. If a substantival model of time underpins persistence then this also determines the nature of change: change is change *over* time, or *in* time. In the absence of (substantival) time there would be no change, and no changing entities. The second implication is that change is also metaphysically derivative of time, and of existence in time.

The position that change is metaphysically derivative of time accords with the static view of change that arises under perdurance. Change is the possession of incompatible properties by different temporal parts, all of which exist ontologically on a par; change is static because time is static. Consequently, becoming is rendered a structural feature of spacetime.

Analogously, under endurance, the metaphysical dependency of change upon time provides for the dynamic quality of change. Although change is given (as it is under perdurance) by incompatible properties at different times, change depends upon a time that flows, or is dynamic, consequently change itself is also dynamic. It is the dynamic, or flowing, nature of time that also permits a model of objective becoming that sees it in terms of a constantly changing reality, rather than as a merely structural feature, as is the case under the static model.

To conclude, although time possesses very different features under the two opposing metaphysical models, the argument here is that both models involve the implicit assumption that time is metaphysically independent of the existence of entities (it is substantival) and that, *qua* substantial, it provides a background that metaphysically underpins both change and persistence. It thereby determines the nature of both change and objective becoming under each model.

1.5.3 The Need to Internalise the Dynamic Aspects of Reality

In this section I argue that it is the assumption that time is external to, and metaphysically independent of, the existence of entities that is the source of the problems for the presentist, as a dynamic theorist. In particular, it renders any dynamic account vulnerable to McTaggart's argument; it also leads to incompatibility with physical theory.

The presentist's commitment to the fundamentality of tense requires a model of objective becoming under which the sum total of what exists is in constant transition; this entails that there is constant change with respect to what is present. An adequate account of change is therefore vital in underpinning objective becoming. I argued above that the presupposition of substantival time implies that change is metaphysically derivative of time; entities exist in, and change with respect to, time. This has the consequence that objective becoming has to be formulated in some manner with respect to time, or in time. In other words, objective becoming has to be explicated as '*temporal becoming*'. Further, this assumption is common to *both* sides in the static-dynamic debate. The implicit assumption, under both metaphysical models, is that, in so far as reality possesses dynamic features, it is time that endows reality with those features. A dynamic reality needs to be underpinned by a dynamic time, and, as argued in § 1.4, a dynamic time is explicated either by time itself flowing, or by reality evolving with respect to a unique, universal time; yet both these approaches lead to intractable problems for the dynamic theorist. A flowing time falls foul of both McTaggart's argument (§ 1.4.1) and issues related to coherence (§ 1.4.2); whereas the search for a privileged, universal time, with respect to which reality evolves, places the dynamic theorist in direct opposition to the results of relativity theory, and so incompatible with physical theory (§ 1.4.3).

Maintaining the presumption of substantival time brings with it the implication that reality evolves *in* time and that objective becoming is necessarily *temporal* becoming. This traps the presentist, as a dynamic theorist, between unacceptable alternatives. To this extent the presentist has good reason to reject this assumption. In Chapter 2 I also argue that this presupposition is unsupported by our current best physical theories. In rejecting this assumption, the presentist needs to establish some means of internalising the dynamic aspects of reality that are indicated by tense. This requires a method of formulating those aspects independently of (substantival) time.

1.6 The Next Steps

In order to pursue an account of presentism that is compatible with physical theory I believe the presentist should reject the 'common false presupposition' that time is substantival, and that entities exist *in* time. At first glance this rejection might appear counter-intuitive since presentism is generally regarded as a theory of *time*. Nonetheless, the principal thesis of presentism is a statement of what *exists*, namely, that only present things exist, and this is (generally) combined with a commitment that reality exhibits objective passage. Presentism is therefore *primarily* an ontological thesis concerning the nature of existence, rather than a thesis about the nature of time *per se*. This leads me to propose two premises as the starting point for establishing an account of presentism that is compatible with physical theory, and I provide support for each in the following chapter.

The first premise is the 'thesis of objective passage' (P1). This is the thesis that:

> **P1**: tense reflects the following fundamental fact about reality: reality exhibits objective passage (or objective becoming) and this is grounded in its intrinsically dynamic nature.

P1 implies that reality is objectively dynamic; in Chapter 2 I argue that this premise is compatible with physical theory. In Chapter 5 I consider the objective correlates of tense and argue that an account of objective passage, sufficient to achieve compatibility with physical theory, requires that the presentist reformulates the standard accounts of persistence and change, to provide a mechanism to internalise the dynamic aspects of reality.

The second premise (P2) concerns the nature of time. It follows from the first premise (that reality is intrinsically dynamic) and a rejection that time is substantival (the 'common false presupposition').

> **P2**: time reduces to the structure of an objectively dynamic reality.

P2 implies that the presentist should subscribe to a reductionist, or relational, account of time. Support for this premise needs to be garnered from our current best theories of physics; this will also be argued for in Chapter 2. Since this thesis aims to provide an approach to presentism compatible with physical theory, an additional preliminary I need to address head-on is the charge that it is eternalism, with its commitment to ontological parity, that is better supported by relativistic physics. This is the task of Chapter 3.

The remainder of the thesis is concerned with the detail of constructing the account, which I shall refer to as 'compatibilist presentism'. A core argument is that modelling reality as intrinsically dynamic requires the development of an appropriate ontological model. Specifically, it requires an ontological model within which it is existence, rather than time, that is dynamic.

CHAPTER 2 – LESSONS FROM QUANTUM GRAVITY: TIME AS THE STRUCTURE OF AN OBJECTIVELY DYNAMIC REALITY

> It's the things that we most take for granted that have the tendency to come back and bite us when it really matters. The nature of space and time is generally taken for granted. But our assumptions about them seem to be inconsistent and as a result, if we are honest, theoretical physics is derailed at its very core. (Majid, 2008b, p. 58)

2.1 Introduction

The aim of this chapter is to provide arguments to justify the two foundational premises, P1 and P2, introduced at the end of Chapter 1. P1 implies that reality is objectively dynamic and P2 states that time reduces to the structure of that objectively dynamic reality. It was argued in Chapter 1 that a 'common false presupposition', that time is substantival and metaphysically independent of the existence of entities, obstructs the presentist in formulating an account that is compatible with physical theory. I believe the presentist should therefore subscribe to a reductionist account of time.

I first argue that none of our current best theories of physics countenance the position that time is metaphysically prior to the existence of entities and, in fact, the conceptual difficulties associated with formulating a successful theory of quantum gravity (QG) appear to suggest that the converse is the case. The metaphysical implication of these conceptual difficulties leads to one of two conclusions: either reality is fundamentally static and unchanging, or, our notions of change, and accordingly of what it is for reality to be dynamic, need to be reformulated. In the second half of the chapter I argue that physics *can* countenance a fundamentally dynamic reality (P1) and that the concept of time employed within physical theory is derivative of objective change (P2). This requires a revision to our standard metaphysical models of change and persistence which rely upon a substantival interpretation of spacetime; I argue that this interpretation is unsupported. I close with the conclusion that a reductionist account of time, in particular one that sees time as the structure of an intrinsically dynamic reality, is the most suitable position for the compatibilist presentist to adopt.

2.2 Time is Now 'Spacetime'

A key result of the Special Theory of Relativity (STR) is the intrinsic entanglement of space and time into one four-dimensional, spatiotemporal reality. It would appear, at first glance, then that the 'common false presupposition', that time is metaphysically independent (something metaphysically separate from the existence of entities), is already undermined from the mere fact that STR is unable to countenance the notion of unique 'times' that can ground change or persistence. In the now, legendary words of Minkowski:

> Henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality. (Minkowski, 1976, p. 339)

If there are no unique times, then the standard construal of change, as incompatible properties at different times,[36] already appears vulnerable. Under STR change cannot be seen as different properties at (uniquely) different times. Nonetheless, perhaps this is simply a matter of terminology – talk of time is, more accurately, talk of spacetime. The suggestion might be that the standard accounts of change and persistence hold, but simply need to be grounded in the concept of spacetime: change is more accurately incompatible properties at uniquely different spacetime points, and it is spacetime, rather than time *per se,* that is metaphysically independent, and serves to ground persistence and change.

It will be seen, in what follows, however, that the notion that spacetime is metaphysically primitive[37] is severely undermined in the move to unify both quantum theory and general relativity theory into a complete theory of

[36] More formally, as defined in Chapter 1 (§ 1.5.1): A (temporally changes) $=_{def}$ A is F at t_1 and A is G at t_2.
[37] From now on I use the term 'metaphysically primitive' as shorthand for 'metaphysically independent of the existence of entities', and so 'substantival'.

quantum gravity. This relates directly to problems that arise in reconciling the nature of time within the two 'ingredient' theories. This is referred to as the 'problem of time'.

2.3 Quantum Gravity and The Problem of Time

In what follows, I argue that all current approaches to formulating a theory of quantum gravity (QG) appear to suggest that neither time, nor spacetime, is metaphysically primitive. Time is either rendered emergent or a reductionist position is implied, one under which time is reduced to the change of one physical variable with respect to others. This section will conclude with a discussion of the metaphysical implications of this.

2.3.1 What is Quantum Gravity?

'Quantum gravity' (QG) refers to a diverse and incipient body of theories which aim to combine quantum field theory (QFT)[38] with the general theory of relativity (GTR) into one, unified theory, encompassing both the gravitational and quantum aspects of matter. There is an obvious interface between the two theories: all matter consists of particles, and so is described quantum mechanically; in addition, all particles (as matter) interact gravitationally. Both 'ingredient' theories have a significant degree of empirical evidence to support them in their respective realms of applicability: QFT applies to matter at the sub-atomic level,[39] whereas GTR describes matter at cosmological scales. However, a theory of quantum gravity is required since GTR is unable to describe 'singularities' adequately; these are points of infinite curvature and energy density associated with the extreme conditions of temperature and density present in the early universe, and within black holes. This indicates the need to include quantum effects within GTR at these scales.

Currently there is no single, universally-accepted approach to a theory of quantum gravity. This is due in large part to the significant conceptual

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[38] Quantum Field Theory represents the successful unification of STR and quantum mechanics (QM) into a relativistic quantum theory.

[39] Referred to as 'Planck scales' where the Planck constant, h, becomes dominant; specifically, lengths $\sim 10^{-35}$m and time $\sim 10^{-44}$s. From here on reference to matter at the 'fundamental level' will refer to Planck scales.

difficulties in reconciling the two ingredient theories. In addition, the extreme conditions associated with the applicability of a quantum gravity theory mean that the empirical discernibility of competing theories is currently out of reach: it is difficult to formulate concrete, testable predictions.

2.3.2 Theoretical Approaches to Quantum Gravity and the Disappearance of Time

The so-called 'problem of time' within quantum gravity arose from the original approach to quantising gravity ('quantum geometrodynamics') established in the 1960s. This attempt involved the construction of a wave equation[40] for the whole universe, referred to as the Wheeler-DeWitt equation (after Wheeler, 1962 and DeWitt, 1967). The problem of time refers to the fact that this central equation lacks a fundamental time parameter and so describes an essentially static wave. Yet this represents the key dynamical equation of quantum gravity. Quantum gravity thus appears to be describing a universe with no time-evolution.

The quantum geometrodynamics programme is now considered to be superseded by mathematically superior approaches. The two main contenders are Loop Quantum Gravity (LQG) and String Theory, which differ in terms of their conceptual starting point. In particular, whether unification should be approached from the standpoint of QFT or from that of GTR.

2.3.2.1 *Covariant Approaches – String Theory*

Approaches that proceed from the conceptual apparatus of QFT are termed 'covariant' and have given rise to string and superstring theory. String theory starts from a modified quantum field theory approach (replacing point particles with one-dimensional extended 'strings') and assumes a background four-dimensional spacetime through which the gravitational field[41] propagates. Despite many different attempts, to date no successful formulation of string

[40] Within the formalism of quantum mechanics physical systems are represented dynamically by a wave equation, i.e., the Schrödinger equation.
[41] The gravitational field is represented by the massless spin-two field of the graviton.

theory has emerged. One suggestion to come from the multitude of different string theories proposed is the idea that the spacetime of GTR is theoretically emergent [42] in a low-energy limit (e.g. Vistarini, 2013). As such, there is no problem of time associated with the covariant approaches precisely because they assume at the outset a classical, background spacetime, which relativistic physics has forced us to reject: this stands as the main criticism of the string theory approach.

Since the covariant approach to QG, exemplified by string theory, relies upon the absolute background spacetime of classical physics in its formulation, any metaphysical interpretation arising from this can be challenged with the move to relativistic physics. Further, the absolute spacetime of string theory functions merely as a theoretical construct in the formalism of the theory. Although the spacetime of GTR can be reconciled within the theory, it is only emergent in the low temperature limit and is not identified at the fundamental level. In conclusion, the covariant approach to QG suggests that spacetime is at best emergent, rather than metaphysically primitive.

2.3.2.2 *Canonical Approaches – Loop Quantum Gravity*

The main alternative approach to formulating QG is described as 'canonical'.[43] This begins from the conceptual commitments of GTR and attempts to quantise the gravitational field directly. Canonical approaches, among which Loop Quantum Gravity (LQG) is the dominant program, continue to suffer from the problem of time identified in the early approach; there is no external background time parameter against which a system can be said to evolve and to which observables can be assigned. This is connected with the fact that the canonical approaches maintain the core conceptual commitment of GTR to background independence.[44]

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[42] 'Theoretically emergent' means that it is not part of the structure of the more fundamental theory that it is emergent from.

[43] 'Canonical' refers to a method, or formalism, for describing the equations of GTR in a manner that emphasises the *dynamical* content of the gravitational field, rather than its *geometric* content; this allows for subsequent quantisation of the field.

[44] Background independence will be discussed in more detail in section 2.4.3. Here it is sufficient to interpret it simply as coordinate, or reference frame, independence.

Two methods are employed to circumvent the problem of time (Isham, 1992). The first approach re-establishes some sense of an evolving reality by extracting an internal time parameter from within the theory (either before or after quantisation). The second approach simply concedes that reality at the fundamental level is timeless; the Wheeler-DeWitt equation is interpreted at 'face-value'.

In the first approach the lack of an external background time parameter requires that time is identified with some internal property of the whole system (matter plus gravitational field). A global time parameter is established such that, overall, the system can be said to evolve 'in time' with respect to this parameter. Consequently, time is re-defined, in physical terms, as the value of physical entities with respect to which other physical quantities are correlated. This equates with a reductionist approach: time is seen in terms of, or *reduced to*, physical 'clocks'. However, such approaches suffer from a whole host of potentially intractable problems, as Isham notes.[45]

Under the second approach the 'timeless' interpretation of reality is simply accepted. The concept of time is assigned a secondary status and described as 'phenomenological'[46] or 'emergent'[47] (e.g. Rovelli, 1990). Nonetheless, for Rovelli the absence of a time parameter in the fundamental equations does not imply that change does not occur. For him 'change is ubiquitous' (Rovelli, 2016, p. 154) but this position is achieved by modelling change, not with respect to some global time parameter, but in terms of relations, or correlations, between physical systems or physical parameters that are time-independent (referred to

[45] For example: 1. disentangling the *physical* modes of the gravitational field from the internal spacetime coordinates; 2. the arbitrary nature of the choice of internal time coordinates conflicts with the fact that the probabilities associated with the Schrödinger equation depend on the time coordinates, this leads to difficulties identifying which of the possible resultant Schrödinger equations is the 'correct' one; 3. in order to be consistent with GTR, any internal spacetime coordinates need to be background independent and not depend on any particular foliation of the manifold; 4. such approaches suffer problems in achieving any sense of a classical evolution of the system.

[46] The term 'phenomenological' is used in the literature to mean that time is not fundamental but is reducible to something more fundamental such as the 'history' of a system, a 'process' or an 'ordering structure'.

[47] It should be noted that here 'emergent' is used in the reductionist sense and not in the same sense as when describing time (in a non-reductionist, classical sense) as being recovered from or emerging from a low energy limit of the theory, such as is described by the string theory approach.

as 'evolving constants'). Though the universe may be timeless when considered as a whole, individual sub-systems can serve as the time parameter (or clock) to measure change in other sub-systems. Rickles (2006) describes Rovelli's 'evolving constants of motion' approach as an attempt to reconcile a fundamentally timeless reality with our observations of dynamics and change. The approach essentially replaces 'the mass of the rocket at t' (which is a background dependent quantity) with 'the mass of the rocket when it entered the asteroid belt', m(0), and 'the mass of the rocket when it reached Venus', m(1), and so on up until m(n)' (2006, p. 43-4). In such a way change can be described in terms of a sequence of background independent quantities, or 'evolving constants of motion'.

An alternative timeless approach, in the sense of asserting that time itself has no ontological significance, is that of Barbour (1999). Barbour considers the timeless interpretation of QG to imply not only that time is illusory but, unlike Rovelli, that therefore there is no change. Although Barbour himself sees his approach as denying time, Rickles (2006) argues that, rather than denying time, Barbour reduces it to points in a relative configuration space. For Barbour change has no objective reality; rather, the whole universe (past, present and future) is modelled by a set of 'instantaneous', three-dimensional relational configurations.[48] All that exists is a vast collection of frozen moments, each being a (spatial) configuration of the universe.

In summary, the canonical approaches to QG all suffer from the problem of time, in that there is a lack of an external background time parameter against which a system can be said to evolve. The responses to this vary depending upon the approach. Either some form of internal time parameter is extracted from the theory (as described in Isham, 1992) or a timeless interpretation of reality, at the fundamental level, is accepted (e.g. Rovelli, 1990 and Barbour, 1999). However, in *both* these cases (apart from Barbour, for whom reality is a static,

[48] Barbour elaborates a Machian (relational) derivation of the classical dynamics of the universe using minimal assumptions about the structure of space, a specification of the initial data to determine dynamical evolution, and the mechanism of this evolution which he describes as 'best matching'. 'Best matching' refers to the tendency for the 'intrinsic difference' between two matter distributions in a dynamical evolution to be minimised. ('Intrinsic difference' is based solely on the masses of the bodies involved and the relative distances between them.)

changeless whole), although the formalism may vary, the notion of evolution 'in time' is recovered by taking a reductionist approach to time. Time is reduced to some *physical* variable, whether physical 'clocks' or 'evolving constants of motion'. In all canonical approaches to QG the concept of time is reduced to something more fundamental, and so none provide support for the idea that time is metaphysically primitive.

2.3.2.3 *Alternative Approaches*

Although quantum gravity is often represented in terms of these two main rival approaches there are other, lesser-known, programs and it is worth briefly mentioning these here. Nonetheless, as with the canonical and covariant approaches, time is reduced to, or replaced by, something more fundamental.

'Causal set theory' (e.g. Markopoulou, 1998 and Bombelli *et al*, 1987) is an approach to quantum gravity that models only the causal structure of spacetime in terms of the causal priority of events with respect to one another.[49] This results in spacetime assuming a discrete structure. Continuous spacetime is seen as an artifice inappropriate at the Planck level; as such, the causal set is defined *prior to* the spacetime manifold. This approach considers the causal structure of events as prior to, and so more fundamental than, spacetime.

Spin Network theory (championed by Penrose, 1971) replaces spacetime points with basic elements comprising units of quantum angular momentum (which is already quantised), without reference to any spatial dimension. This approach evolved into 'twistor theory' (also developed by Penrose) which preserves the causal, or light cone, *structure* of spacetime whilst demoting spacetime points. The latter are merely 'secondary constructs', with the paths of light rays comprising the more 'primitive element' in the theory.

2.3.3 Summary: The Problem of Time and its Metaphysical Implications

An admittedly cursory review of the main approaches to quantum gravity theory has been given above. Though there is no consensus on what the final

[49] 'Causal dynamical triangulation' is another similar approach (e.g. Ambjørn *et al*, 2008).

theory may look like, all approaches appear to indicate that a successful theory will significantly change our conception of time.

Under covariant theories, such as string theory, the spacetime of GTR emerges only in the low temperature limit of the theory and is not identified at the fundamental level. In the case of the canonical theories, the lack of a fundamental time parameter (the problem of time) gives rise to two alternative approaches. The first identifies an internal time parameter by defining time in terms of physical clocks, and so is reductionist. The second approach accedes to the denial of time at the fundamental level, as overtly implied by the Wheeler-DeWitt equation. Theories of the third type, considered above, also all abandon the fundamentality of spacetime in favour of defining the fundamental elements of the theory in terms of causal structures.

The interpretation put on these results varies. Callender (2010) sums it up thus:

> Some physicists argue that there is no such thing as time. Others think time ought to be promoted rather than demoted. In between these two positions is the fascinating idea that time exists but is not fundamental. A static world somehow gives rise to the time we perceive. (p. 59)

Both Rovelli (2016) and Barbour (1999) take the results at face value and hold that time has no ontological significance: time is 'unreal'. Similarly, Callender considers time 'a convenient fiction that no more exists fundamentally in the natural world than money does' (*ibid.*, p. 65). Contrary to our best intuitions Heller (2008) also concurs that 'many approaches to quantum gravity suggest [… that] on the fundamental level time either does not exist, or has drastically different properties from what we are accustomed to in the macroscopic world' (p. 264). Others[50] argue that QG implies that time is emergent rather than an illusion.

If, as the contender theories indicate, spacetime is not present at the fundamental level of reality, then none of the proposed models of quantum gravity provide support for the premise that time, or spacetime, is

[50] For example, Butterfield and Isham (1999) and Butterfield (2002)

metaphysically primitive (i.e., independent of the existence of entities). At best, time appears 'emergent', in both senses in which the term is used: either in the reductionist sense, where time is re-defined in physical terms as the value of physical entities with respect to which other physical quantities are correlated, or, in the sense of only appearing in a low energy limit of the theory.

One metaphysical implication that appears to follow from this is that the notion that existence is necessarily existence *in* time (or spacetime) is undermined. Although spacetime might disappear at the fundamental level there is still an existent *something* (for example, the quantum vacuum or zero-point energy) to which our fundamental theories apply. Existence must be prior to spacetime. This leads to a second implication: contrary to the interpretation that reality lacks objective change, the disappearance of time provides the possibility that the time that emerges is the structure of, or derivative of, an objectively *dynamic* reality.

Given the disputes around the nature of time arising from quantum gravity it would appear, as Saunders (2002, p. 291) concludes, that 'there is everything to play for' in terms of metaphysical interpretation. Quantum gravity theories are, however, nascent, and as such it is too early to predict which of the various approaches might succeed; consequently, it is too early to judge their full metaphysical implications. Nonetheless, in what follows I describe how the conceptual core of the problem of time is already lurking within GTR and I argue that, whichever theory of QG ultimately succeeds, the notion of time as metaphysically primitive is already unsupported within our best theories of physics. Consequently, those theories do not undermine premise P2: the premise that time reduces to the structure of an objectively dynamic reality.

2.4 The Conceptual Core of the Problem of Time

Many commentators would agree with Isham's (1992) intuition that obstructive foundational metaphysical assumptions are, at least partially, responsible for the difficulties encountered in reconciling GTR with QFT, since the foundational axioms of the two theories treat time in radically different ways.[51] This represents the key conceptual challenge that needs to be overcome in unifying these two ingredient theories into a successful theory of QG.

> I feel it is correct to say that the problems encountered in unravelling the concept of time in quantum gravity are grounded in a fundamental inconsistency between the basic conceptual frameworks of quantum theory and general relativity (Isham, 1992, p. 108).

In what follows, I contrast the concept of time under both QFT and GTR. I proceed to highlight that the conceptual core of the problem of time lies with the commitment to background independence within GTR. This leads to the unavoidable result that objective change has to be denied or reformulated. Further, the need to combine two core commitments of the separate theories suggests that, irrespective of the exact theory of QG arrived at, the notion of time (spacetime) as metaphysically primitive is inevitably undermined.

2.4.1 The Concept of Time Within Quantum Theory

Quantum systems are described by the deterministic evolution, in time, of a wave function described by the Schrodinger equation. Within QFT time thereby retains the theoretical role it possesses within classical, Newtonian physics, in that it comprises an absolute background against which the quantum fields (for example, the electromagnetic fields) propagate and evolve. Here time is an abstract concept, it is external to the system being modelled and is non-dynamical.[52] As Unruh and Wald (1989) have shown, time under quantum theory is truly abstract in the sense that no physical clock can actually measure it, in the sense of exactly corresponding with it.[53] By rendering time a

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[51] For example, Crowther and Rickles (2014) argue that the successful development of a definitive theory of quantum gravity crucially hinges upon a thorough reassessment of our fundamental metaphysical principles, especially with regard to our models of time and change. Others adopting a similar viewpoint include Smolin (2015), Rovelli (2016) and Butterfield and Isham (2001).

[52] Where 'non-dynamical' is used in the sense of 'not interacting with the system being modelled'.

[53] Unruh and Wald (1989) show that such a condition is incompatible with such a clock, as a physical system, having a positive energy. According to QM, any physical clock always has a finite probability of running backwards with respect to Newtonian time.

background parameter, both quantum theory and Newtonian classical mechanics can be considered theories *par excellence* for modelling isolated sub-systems of the universe. The evolution of any system is referenced to a clock sitting outside the system being modelled.[54]

There are two problems that arise from this concept of time, which imply that such a view will invariably have to be abandoned in any successful theory of quantum gravity. In the first case, as noted, the classical spacetime of Newtonian mechanics has been replaced by relativistic spacetime, under which space and time are intrinsically entangled into one four-dimensional reality. Secondly, any proposed theory of quantum gravity would, by necessity, aim to model the *whole* universe (as does GTR). Since it is not possible to situate a clock 'outside' the universe (as the universe is a completely closed system) there is no external time parameter, or fixed background, against which the universe might evolve. The notion of time as an external background, with respect to which the universe evolves, will need to be surrendered. As Smolin (2001, p. 7) notes 'any clock, and any measuring instruments referred to in the interpretation of the theory, must be part of the dynamical system which is modelled'. It is generally accepted, therefore, that any successful theory of quantum gravity would need to take on board the key conceptual commitment of GTR to background independence; this is why approaches to QG seek to identify some form of internal time parameter within the variables of the theory.

2.4.2 The Concept of Time Within GTR

In order to understand the very different nature of time, and the concept of background independence, within GTR, it is first useful to outline the basic elements of the theory.

[54] It should be noted that in STR, also, time can be rendered a background parameter within the formalism of the theory. Simply, the fixed background time of classical physics is replaced with the set of possible relativistic inertial reference frames, defined by the Lorentz transformations of STR. It is because of this that the unification of STR with QT into relativistic quantum mechanics (or 'quantum field theory', QFT) has been achievable.

GTR is the most comprehensive theory of gravitation in physics and, as with quantum theory, benefits from significant empirical support. The dynamics of GTR are encoded in the Einstein Field Equations (EFE) which unify gravitational phenomena with the geometry of spacetime.

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

The left-hand side of the equation represents the geometry of spacetime, indicated by the Einstein tensor, $G_{\mu\nu}$. The right-hand side describes the total mass-energy present in the universe, encoded in the stress-energy tensor, $T_{\mu\nu}$. A given solution of the equations[55] describes the physical situation where the gravitational field (as the geometry of spacetime) interacts with the matter fields distributed over it. In the now famous words of Misner *et al* (1973, p. 5) 'Space acts on matter, telling it how to move. In turn, matter reacts back on space, telling it how to curve'.

Under GTR spacetime is *identified* with the gravitational field[56] and this identity represents a revolution in the concept of spacetime from all previous theories. Spacetime is no longer seen as an inert, external background against which change and evolution are modelled: it is to this extent that GTR is seen as demanding a 'background-independent' approach, and it is this that differentiates the theory from preceding spacetime theories.[57] Since both GTR and QG aim to model the *whole* universe, the background independence of GTR is seen as a key commitment to be maintained under any successful approach to QG. As will be seen in the next section, this commitment has significant consequences for the standard notion of change and indicates that this concept needs to be reformulated.

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[55] A given solution of the EFE is described in terms of a triple $< M, g, T >$ consisting of a four-dimensional manifold, *M*, of coordinate points (or a configuration space), the metric tensor, *g*, which defines the distances and geometrical relations between the points, and the stress-energy tensor, *T*, which describes the distribution of mass-energy.
[56] This is referred to as Einstein's 'principle of equivalence'.
[57] STR is not fully background-independent due to fact that there is no *reciprocity* between the Minkowski metric and matter; Minkowski spacetime dictates the inertial behaviour of matter but the latter has no reciprocal effect back on spacetime.

2.4.3 The Conceptual Core of the Problem – Background Independence

The 'background independence' of GTR (also referred to as 'diffeomorphism invariance') differs from, and is a stronger requirement than, the 'general covariance' of previous spacetime theories.[58] In simple terms, 'diffeomorphism invariance' means that any solution of Einstein's equations (as the metric and matter fields) can be 'dragged' over the spacetime manifold to provide a physically equivalent solution. A diffeomorphism is in essence a mathematical transformation that maps one spacetime point onto another. This entails that the physical observables (or physically meaningful quantities)[59] of the equations of GTR are *independent* of spacetime coordinates and, as Weinstein (2001, p.92) notes this means that the gravitational field 'defines its own background – it is both "stage" and "actor"'.

This requirement for background independence has a significant consequence. If the physically meaningful quantities are independent of spacetime coordinates, then a difficulty arises in defining the evolution of a system: there is no background against which that evolution can be defined. This results in what is referred to as the 'frozen formalism' of GTR: the states of the system (e.g. the universe) which were previously taken to represent different physical conditions at different times are now equivalent. Thus, the notion of a static picture of reality is *already* lurking within classical GTR,[60] even before attempts are made to quantise the theory within quantum gravity. It is the requirement

[58] General covariance refers to the invariance of the dynamical equations under an arbitrary coordinate transformation between inertial reference frames: any dynamical theory, including Newtonian mechanics, can be written in a generally covariant form. It is accepted that the equivalence implied here between background independence and diffeomorphism invariance is strictly inaccurate. There are subtle and extremely technical differences between the terms 'background independence', 'general covariance' and 'diffeomorphism invariance' as they function within the formalism. Both Vassallo (2015) and Pooley (2015) provide a useful discussion of the differences in the uses of these three terms. These differences are not pertinent to the discussions here.

[59] For example, momentum.

[60] Although the roots of the problem of time lie within GTR, this does not present such a fundamental problem as occurs with the move to QG. This is because it is possible for a global time parameter to be defined within GTR by slicing the manifold preferentially to produce space-like hypersurfaces of equal time. A global time parameter can be arbitrarily assigned and, once the Einstein Field Equations have been solved, some sense of evolution with respect to this parameter can be achieved.

under GTR for background independence, with its absence of an external time parameter, that leads directly to the timeless aspect of formulations of QG and motivates the conclusion that reality is fundamentally changeless.

The problem of time becomes even more acute when attempts are made to quantise the spacetime of GTR, and establish a theory of quantum gravity. The equivalence of the physical (gravitational) field with the spacetime of GTR means that the entity to be quantised *already contains* both time and space. Further, preserving the background independence of GTR means that the resultant, quantised system cannot evolve *with respect to* time (since time is already present in the quantised state). Weinstein and Rickles (2018) describe the situation thus:

> […] the problem is roughly that in quantizing the structure of spacetime itself, the notion of a quantum state, representing the structure of spacetime at some instant, and the notion of the *evolution* of the state, do not get any traction, since there are no real 'instants' (§ 5.1).

This represents the very core of the problem in reconciling the two 'ingredient' theories. Majid (2008) succinctly describes the dichotomy: the postulated quantised particles for gravity (gravitons) must, in effect, both *move within* spacetime and *be* spacetime. This is the sense in which spacetime (as gravitational field) is both 'actor' and 'stage', and this is a direct consequence of the background independence of GTR. Majid takes this to mean that our current concepts of space and time are fundamentally flawed and successful implementation of quantum gravity 'would likely entail a completely new concept of space and time' (p. 69). Similarly, many commentators[61] believe that resolving the core conceptual issues underpinning the problem of time in quantum gravity relies upon a correct interpretation of the meaning of background independence within GTR. I shall return to this in section 2.6.4.

In summary, the problem of time arising in QG has its roots in the commitment to background independence within GTR. This has the result that the system

[61] For example, Belot and Earman (2001), Maudlin (2002) and Rickles (2006).

modelled does not evolve with respect to time, and if there is no evolution with respect to time, the existence of objective change is undermined.

2.4.4 The Metaphysical Implications Revisited

Despite the lack of consensus over the correct approach to QG, any successful theory will need to incorporate the key conceptual commitments of the two ingredient theories. From these two metaphysical conclusions seem to follow.

The first commitment proceeds from GTR and this is the requirement for background independence. As described in § 2.4.3, this means that no genuine physical observable can assume different values at different times. This has implications for our notions of change and evolution. The idea of objective change as different intrinsic properties at uniquely different times has to be surrendered as incompatible with our existing best physical theories. Spacetime can no longer be considered as providing an external background against which change and evolution occur. The lack of a unique time parameter, and the consequent picture of a static reality that emerges from QG, arise directly from this commitment of GTR. The formalism is 'frozen' on the assumption that change is given as different physical observables at (uniquely) different times. None of this should be surprising, however, since the notion of a uniquely definable time parameter is already rejected with the unification of space and time under STR. The metaphysical conclusion that follows from this is:

> **M1:** either reality is, at the fundamental level, static and unchanging or our notion of change, as it is metaphysically speaking, has to be reformulated.

The second metaphysical conclusion follows from the need to combine the requirement (from QFT) to quantise the gravitational field with the equivalence between the gravitational field and spacetime (from GTR). As described above, the resultant quantum state (which contains spacetime) cannot exist *within* spacetime, rather the continuous, classical spacetime able to support evolution and change, somehow *emerges* from the, more fundamental, quantum state in the limit of low energy conditions. If spacetime is derivative of a more fundamental entity (the quantum state of the gravitational field) this has the following metaphysical implication:

> **M2:** Spacetime is not metaphysically primitive.

M1 and M2 are two metaphysical conclusions that arise from the problem of time. Taken together they present two alternative interpretations of reality.

The first alternative presented in M1assumes that change can *only* be construed as different intrinsic properties at uniquely different times. Under this assumption reality is, at the fundamental level, static. There is no objective change or evolution since (from M2) spacetime is not metaphysically primitive and so it cannot underpin objective change at the fundamental level. In this case, since spacetime is emergent, an explanation needs to be given as to how it emerges from what is a fundamentally static reality.

The second interpretation (of M1) suggests that it is our concept of change that requires revision, rather than abandonment. In the absence of spacetime at the fundamental level (M2) there is nothing to ground a concept of change regarded in terms of different intrinsic properties at different times. Instead, this presents the option that reality is intrinsically and fundamentally dynamic, and that spacetime emerges, in some manner, from this dynamic reality.

In the following, I argue that support from physical theory can be gained for the second interpretation. I argue that the concept of time in physical theory is derivative of objective change in reality, contrary to our standard metaphysical models. I also argue that though time (as spacetime) may not exist at the fundamental level, physics can countenance the view that reality is fundamentally dynamic. In the remainder of this chapter I support the premise that our concept of change needs to be reformulated. In Chapter 1 I argued that the standard metaphysical models of change rely upon a substantival interpretation of time; here I argue that such an interpretation of the spacetime of GTR is unsupported. An alternative, structuralist model of spacetime not only aligns better with the conceptual requirements of QG but it also provides a route to modelling spacetime as the structure (and so, derivative) of an objectively dynamic reality, to the advantage of a compatibilist model of presentism.

2.5 Physics is Consistent with an Objectively Dynamic Reality

In this section I argue that, despite the problem of time, our fundamental physical theories are compatible with the objective reality of change and, indeed, that the meaning of time as it functions within those theories supports the view that time is derivative of objective change.

2.5.1 Time: a 'Glorious Non-Entity'?[62]

The problem of time within quantum gravity provides good reason to question the view that time is metaphysically primitive. However, a cursory historical review of the way in which time is defined within physical theory also appears to suggest that, contrary to our dominant metaphysical models, time is, in fact, derivative of objective change.

Since the very beginnings of scientific theory, time has been defined operationally, in terms of the objective motion of bodies. As Aristotle noted, 'Time is neither identical with movement nor capable of being separated from it' (*Physics*, IV. 11). Reflection on the different historical methods used to measure time shows that it always requires a comparison in the *change or evolution* in one system (designated the 'clock') with respect to another physical system. For example, 'solar time' is given by the relative *motion* of the sun; 'sidereal time' refers to the *distance moved* by the stars. This continues through to the present day, where the second is defined in terms of an *oscillation* between two energy levels of the caesium atom.[63]

Though we speak (inaccurately) of *measuring* time, Peres (1980) and Rovelli (2016) both highlight that we never actually measure time itself: time is not an observable or a dynamical variable, unlike position, energy and momentum. All

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[62] This description derives from Brown and Pooley (2006).

[63] The 13th meeting of the International Committee of Weights and Measures, in 1967, adopted the following definition: 'The second is the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium-133 atom'.

so-called 'properties of time' must therefore 'be abstractions from *relative* motions and their empirical laws' (Zeh, 2007, p. 12). Any measurement of time, or more accurately duration, is just a comparison in the evolution of one physical system with respect to another, which allows us to assign an ordering variable to the physical system being considered. Any measurement of time therefore *presupposes* objective change in the sense of the evolution of a physical system.

All physical theories rely upon such an instrumentalist definition of time. Within STR simultaneity is defined by way of a synchronisation procedure involving the physical transmission and reception of light signals. Clocks within STR are 'spatially-localised physical clocks' (Isham, 1992) and time is 'proper time' along the world-line of such a clock, rather than coordinate time. STR can thus be considered to be a theory 'about observable luminal relations among physical events' (Rea, 2003, p. 274) rather than a theory about *time per se*. In a similar vein, Brown (2005, p. 136, p. 142) refers to the Minkowski metric as a 'codification' of the *behaviour* of rods and clocks.

Under GTR, Einstein showed that the rate of clocks must depend on their position in a gravitational field: clocks closer to gravitating bodies run slow relative to clocks farther away. But relativity makes statements about *actual* clocks, not time in the abstract. In other words, it is not that *time*, as such, passes more slowly.

An interesting contribution to the debate is reviewed by Zyga (2012) who describes the work of Sorli and Fiscaletti (2012). The latter argue that the relativistic kinematic effects of STR can better be described by moving away from seeing time as the fourth dimension of Minkowski spacetime and instead seeing time as a quantity measuring change (or the 'numerical order of motion'), in particular, the motion of photons. Their idea is that time should no longer be seen as a dimension *through which* entities move.

In conclusion, time, as it functions within our fundamental physical theories, is defined in terms of physical clocks (whether light clocks, body clocks or atomic clocks). Such systems involve *motion* of one form or another. Indeed, physicists define a clock as follows: 'any clock is a dynamical system which passes through a succession of states' (Peres, 1980, p. 552). So, far from being fundamental, the concept of time (as used in science) is derivative of objective change.

The problem of time (in the sense of the lack of a time parameter at the fundamental level of reality) should therefore come as no surprise. Time, as it functions within physical theories, is reduced to, or defined in terms of, physical clocks, yet no physical clock can 'sit outside' the universe and so provide the time parameter required for modelling its evolution. This is precisely why GTR, and emerging theories of QG demand a background-independent approach. This simple fact is consistent with the view that our theories are currently *inadequately modelling* a dynamically evolving universe, rather than suggesting that those theories are *accurately describing* a static universe. As Rovelli emphasises, the absence of a time parameter from the fundamental equations does not imply that *change* does not occur, it just has to be modelled differently within the mathematical formalism.

2.5.2 Physical Reality is Fundamentally Dynamic

In this subsection I argue that the disappearance of time (spacetime) at the fundamental level does not imply a reality that is objectively static at this level, in fact there is good reason to suggest that reality *is* fundamentally dynamic.

It was argued above that time, as it figures within physical theory, is defined in terms of, and so derivative of, physical systems or matter in motion. That matter (or mass-energy) is intrinsically dynamic, and so can function as a physical 'clock', can be understood by combining two fundamental equations: Einstein's equation (i), stating the equivalence between mass, m, and energy, E, and Planck's equation (ii) which describes the discrete, or quantum, nature of energy (where c is the velocity of light, υ is frequency of oscillation, and h is Planck's constant).

(i) $\mathrm{E}=\mathrm{m}c^2$

(ii) $\mathrm{E}=h\upsilon$

(iii) $\therefore \upsilon=\mathrm{m}c^2/h$

Equation (iii) expresses the fact that any mass provides for an intrinsic 'clock', ticking with a frequency, υ, proportional to its mass-energy. This dynamic aspect of mass-energy is also suggested by the fact that it is *momentum*, rather than mass-energy that is the more fundamental, physical quantity. The Einstein Field Equations (of GTR) represent a complicated combination of momentum and energy and it is these quantities (rather than mass) that are primary; momentum is an intrinsically dynamic quantity, whereas mass is intrinsically static. It is for this reason that gravity deflects light; even though photons are massless they do possess momentum (given by h/λ).

The fundamental equations of physical theory therefore provide some support to regard matter (mass-energy) as intrinsically dynamic. Nonetheless, in the absence of matter, the formalism of QFT also suggests that reality, at the fundamental level, exhibits a dynamic nature, as the following describes.

The realm of applicability of any successful QG theory represents extremes of temperature and energy density where quantum effects (described by QFT) are dominant. It was noted earlier that, though time may be absent at the fundamental level, there is still something (the quantum gravitational field) to which our fundamental theories apply. Under QFT, even in the vacuum state (i.e., in the absence of matter) the quantum field has a non-zero energy; it can be characterised by positive values of energy and momentum. Not only is this field not empty, it is also not static. As a consequence of the Heisenberg Uncertainty Relations,[64] the quantum field is constantly fluctuating through the creation and annihilation of particles and anti-particles (Kuhlmann *et al*, 2002 and Redhead, 1982, pp. 86-88). Though time may be absent, reality at the fundamental level is, nonetheless, objectively dynamic.

At this point the following concern might arise: if reality is fundamentally dynamic, in the way described, how might concepts such as frequency and momentum be applicable and understood without a notion of time? This

[64] These relations express an imprecision in the simultaneous definition of paired measurement variables, paradigmatically those for position and momentum, and energy and time. This has the consequence that no experiment, *in principle*, permits a precise determination of the values of e.g. both position and momentum. It is the relation between energy and time that gives rise to the non-zero energy of the quantum vacuum state.

question leads directly into the discussions in Chapter 6, which propose an ontology capable of reconciling presentism (and any theory committed to an objectively dynamic reality) with physical theory. The ontology is constructed on the premise that motion is (metaphysically) primitive and time derivative. As a consequence, momentum and frequency are derivative of mass in *motion*, rather than mass in time. Further, this is reinforced in the three fundamental equations given above, none of which include a reference to time.

2.6 Time for Change?

Consideration of our current physical theories supports the conclusion that time is not metaphysically primitive, yet reality is objectively dynamic. This is at odds with our dominant metaphysical models which assume the metaphysical priority of time over change and persistence. I argued in Chapter 1 that those metaphysical models rely upon a substantival interpretation of spacetime. I argue in this section that the terms of the debate between substantival and relational interpretations depend on a misguided reading of the equivalence between spacetime and gravitational field within GTR. An alternative, structuralist, interpretation permits a better understanding of the background independence of GTR and points towards the development of an alternative ontological scheme better aligned to the conceptual foundations required by quantum gravity. This scheme is developed in Chapter 6.

2.6.1 The Assumption of Substantivalism

In Chapter 1 I argued that under our predominant metaphysical models (the 'static' and 'dynamic' models) substantival time provides the background with respect to which objects both persist and change: objects both persist and change *in time*.

The substantival view of time (or spacetime) has its origins in the absolute space and time which served as the arena of classical Newtonian dynamics. Nonetheless, such a view of spacetime is also considered to be motivated by the identification of spacetime with the gravitational field under GTR. In the following I review the extent to which the spacetime of GTR supports a substantivalist reading, and conclude that it is by no means clearly supported.

2.6.2 Interpreting the Spacetime of GTR - Is Substantivalism Supported?

The identification of spacetime with the gravitational field under GTR reinvigorated the long-standing debate between absolute (or substantival) and relational conceptions of spacetime. Substantivalism is the view that spacetime 'can be said to exist and to have specified features independently of the existence of ordinary material objects' (Sklar, 1977, p. 161). Spacetime as a 'substantival' entity is ontologically separate from matter and its relations. If spacetime is ontologically separate from matter and its relations, this supports a position which sees spacetime as metaphysically primitive. Such a view is also associated with a kind of realism about spacetime that characterizes spacetime as a container, or a pervasive medium, within which things both exist and evolve. Such an interpretation of spacetime supports the role that time plays within our dominant metaphysical models.

The converse view, relationism, rejects the ontological elevation of spacetime to a separately existing entity: rather, spacetime *just is* the existence of spatiotemporal relations holding between material entities. Under this view, spacetime is ontologically derivative of the objects and matter comprising the universe; a universe with no matter would have no spatiotemporal relations.

In referring to Einstein's gravitational field equations (§2.4.2), Heller (2008, p. 254) suggests that 'although the two sides are connected by an equality sign, the question arises: what is "physically prior" spacetime geometry or matter distribution?'. Certainly, for Einstein, in implementing 'Mach's Principle',[65] the physical priority is the distribution of matter; it is this that gives rise to the curvature of spacetime. If spatiotemporal relations are derivative of the distribution of matter, then this provides a case for relationism. Nonetheless,

[65] Einstein was heavily influenced by Mach's positivist and relationist programme. Mach sought to eliminate absolute Newtonian spacetime in his 'Science of Mechanics' (1883) by asserting that the inertial mass and inertial motion of a body arose solely from the influence of all other matter in the universe. Einstein referred to as 'Mach's Principle' his principle that the metric of spacetime (which describes the gravitational-inertial behaviour of matter) is solely determined by the mass-energy of the universe.

the case for substantivalism can also be made and the following assesses the extent of the support for this interpretation.

2.6.2.1 *The Argument for Substantivalism*

Substantivalists ostensibly gain support from the identification of spacetime with the (substantival) gravitational field. Further support is gleaned from the discovery of a solution to the Einstein field equations by de Sitter (in 1917) which permits a universe devoid of matter to have a determinate spacetime structure, contrary to Mach's Principle.[66] Such solutions, known as 'vacuum solutions', represent the case where the energy-momentum tensor, $T_{\mu\nu}$, vanishes. If spacetime has structure in the absence of matter, and its relations, this lends support to the view that spacetime is metaphysically prior to matter, and so substantival.

It is not clear, however, that metaphysical conclusions favouring the substantivalist automatically follow from the existence of vacuum solutions. Heller (2008) argues that this is simply explained by the formalism of the geometry used, with no necessary ontological implications. Within (ordinary) geometry, any curved surface, or space, can always be approximated locally by a flat surface. As such any physical theory, described in terms of ordinary geometry, will always have such structural features and so fail to implement Mach's Principle fully. Indeed, the flat, Minkowski spacetime of STR (which is devoid of matter) represents one such solution and is incorporated into the spacetime of GTR as a limit. Since the metric of Minkowski spacetime arises in virtue of the causal structure of the relations between *possible* events, the existence of vacuum solutions of the EFE provides no reason to adopt an extreme realism with regard to the spacetime of GTR.

In considering whether GTR commits one to the physical existence of spacetime, Butterfield and Isham (2001) urge caution in reifying spacetime and adopting the sort of scientific realism about spacetime that became popular in the 1960s.

[66] It should be noted, though, that in the Friedman-Robertson-Walker-Lemâitre Big Bang models, which represent solutions of the EFE best matched to *our* universe, the Minkowski background spacetime structure does disappear and there is complete determination of inertia by global matter distribution, in support of Einstein's Mach Principle.

They argue that both QFT and GTR rely on modelling spacetime in terms of *mathematical* points but that this does not require the adoption of realism about those points. They refer to Whitehead's 'fallacy of misplaced concreteness' in 'positing a one-to-one correspondence between what is undeniably real in the Platonic realm of mathematical form, and what is, more problematically, "real" in the world of physical "stuff"' (p. 53). In addition, the existence of translation invariance[67] within Minkowski (and indeed, Newtonian) spacetime counts against an interpretation that spacetime points have any physical reality.

2.6.2.2 *The Hole Argument*

The position that spacetime points are physically real is referred to as 'manifold substantivalism'. GTR, as a spacetime theory, can be described in terms of a manifold of events, a metrical structure and matter fields; this provides alternative options for formulating substantivalism. Aside from the objections outlined above, by far the strongest argument against manifold substantivalism is Einstein's 'hole argument'.[68] The argument claims that the background independence of GTR implies a radical indeterminism if GTR is combined with a view that spacetime points are physically real.

The background independence of GTR (which permits matter and metrical fields to be spread over the manifold in different ways) allows the same physical processes to be located differently in spacetime. For the manifold substantivalist since the manifold, as spacetime substance, is ontologically separate from matter, any two distributions of metrical fields over the manifold,

[67] This arises from the general covariance of all dynamical theories as explained in footnote 58 above.

[68] The manifold is a set of spacetime events organised into a four dimensional coordinate space, or system. The metric (or metric field $g_{\mu\nu}$) specifies the structure of those spacetime events (e.g., the direction of past and future, the intervals between events and relations of simultaneity). The matter fields represent the total mass-energy of the universe. The background independence of GTR implies that the metric and matter fields can be distributed over the manifold in different ways and yet be physically equivalent (they are 'independent' of the background manifold). The different ways in which the metric and matter fields can be so distributed are related mathematically by a 'transformation', or 'mapping' from one to the other. The hole argument considers the scenario where part of the manifold contains a 'hole'. The associated transformation is the 'hole transformation'. A comprehensive discussion of the issues involved is provided by Norton (2018). Transformation equations are also explained in Appendix I to this thesis.

related by the hole transformation, represent physically distinct systems. Yet, the argument shows that it is impossible to distinguish such physically distinct systems, either through observational verification or via the determining power (e.g., the laws) of the theory. It appears that determinism fails under such an interpretation of GTR. Consequently, Belot and Earman (2001, p. 228) argue that ‘one must be a relationist in order to give a deterministic interpretation of general relativity’.

2.6.2.3 *A Possible Alternative – Metric Essentialism*

The substantivalist is not, however, committed to manifold substantivalism and might alternatively subscribe to a ‘metric essentialism’ (Dainton, 2010). Under this, the postulated substantival spacetime field includes the metric field ($g_{\mu\nu}$).[69]

The problem that arises here is that the metric field also includes energy and momentum; this means that the question arises as to how the spacetime field can now be said to be independent of, or prior to, matter in the manner required by the substantivalist. Further, since $g_{\mu\nu}$ and $T_{\mu\nu}$ (total mass-energy) are interdependent, different matter fields result in different metrics (metrical structure is dynamic) and so metrical structure varies from model to model. As such it cannot be said to be ‘essential’ in the sense of being an invariant feature of spacetime. Belot and Earman (2001) suggest that such ‘sophisticated’ substantivalism ‘is in fact a pallid imitation of relationalism’ which serves merely to circumvent the ‘challenges posed by contemporary physics’ (p. 249).

2.6.3 Conclusion - The Need for Revision to Our Metaphysical Models

Subsection 2.4.4 suggested that the problem of time within quantum gravity indicates that our standard metaphysical models of time and change require revision. These models rely upon a substantival reading of the spacetime of GTR, yet the arguments given above indicate that the case for a substantival reading is not unambiguously supported. It is also noted (section 2.4.3) that

[69] The metric (or metric field), $g_{\mu\nu}$, is introduced in §2.4.2 and further described in footnotes 55 and 68.

many believe the conceptual difficulties in formulating quantum gravity centre around the correct interpretation of the background independence of GTR. It is therefore vital that our metaphysical models align with an appropriate interpretation of the spacetime of GTR, one that is also consistent with the conceptual requirements indicated by emerging theories of QG.

In working towards such an appropriate interpretation, the following section argues that the debate between relationism and substantivalism now appears redundant and, further, that consideration of quantum gravity suggests that a structuralist account of spacetime better meets the conceptual requirements presented. This conclusion signposts the route towards alternative metaphysical models of change and persistence, ones able to support a compatibilist account of presentism.

2.6.4 The Case for Structuralism

Though the arguments against a substantival interpretation are significant, it is by no means clear that the spacetime of GTR unambiguously supports the alternative, relational, interpretation. Indeed, Butterfield and Isham (2001, p.52) argue that GTR supports relationism to the extent that the four-dimensional metric of spacetime is dynamical (and so depends on or varies with the matter it describes); however, it supports substantivalism in that 'the *presence* in the theory of the metric and connection is not determined by the spatio-temporal relations of material bodies'.

This ambiguity in the interpretation of the spacetime of GTR seems to arise from the feeling that one side of the Einstein Field Equations (§ 2.4.2) has to take physical priority over the other, in a causal sense. Indeed, this is what is implied in the earlier quotation from Misner *et al* (1973).[70] Rather than debating which side of the equation has physical priority – spacetime in the case of substantivalism or matter in the case of relationism – an alternative position is to take the *equivalence,* between spacetime and the gravitational field, in the Einstein Field Equations more seriously. Such an equivalence can equally be

[70] 'Space acts on matter, telling it how to move. In turn, matter reacts back on space, telling it how to curve.'

seen as representing a physical field with metrical properties. Support for this interpretation comes from quantum gravity. QG appears to require that gravity is treated as a physical field, if for no other reason than to achieve the necessary quantisation, and this is what the various approaches outlined previously suggest. This has led some to consider whether the debate between relationism and substantivalism is, in fact, now redundant.

Brown (2005) argues (along similar lines to Rovelli, 1997) that it is misleading to make the distinction between matter fields and spacetime (as given by the spatiotemporal metric, $g_{\mu\nu}$) where the latter is the 'arena' within which matter and physical processes occur. They argue that $g_{\mu\nu}$ is justifiably considered to be an autonomous physical field, albeit with certain unique features (such as the fact that it couples with every other physical field and is non-vanishing for all spacetime). Brown quotes Rovelli (1997):

> A strong burst of gravitational waves could come from the sky and knock down the rock of Gibraltar, precisely as a strong burst of electromagnetic radiation could. Why is the … [second] 'matter' and the … [first] 'space'? Why should we regard the … [first] burst as ontologically different from the second? Clearly the distinction can now be seen as ill-founded. (Rovelli, 1997, p.193)

For Rovelli, Einstein's equation of the gravitational field with spacetime geometry can be understood in two, mutually exclusive, ways: *either* that the gravitational field is (ontologically) nothing over and above the distortion of spacetime geometry *or* that spacetime geometry is a 'manifestation of a particular physical field, the gravitational field'. Rovelli prefers the latter.

Rickles (2008b) argues that the 'dual role'[71] of the spatiotemporal metric, and the reciprocity between matter and spacetime (which is what distinguishes GTR from previous spacetime theories) means that there is an essential 'ambiguity over the ontological nature of the field: spacetime or material object' (p. 136), which itself arises from Einstein's principle of equivalence. To this extent there

[71] 'Dual role' refers to the fact that the metric, $g_{\mu\nu}$, determines both the geometrical properties, or structure, of spacetime and the properties of the gravitational field.

is some justification for Rynaseiwicz's (1996) claim that the debate between substantivalism and relationalism is 'outmoded'. Rickles agrees and argues that both relationism and substantivalism ultimately lose out to structuralism:

> According to the relationalist (about motion) all motion is relative motion. But motion relative to what? The gravitational field? But if it is the gravitational field, then we face a problem in GR (and background independent theories in general): is this field spacetime or matter? Einstein, and Rovelli, claim that the gravitational field should be *identified* with spacetime. Here we see that both positions can get a foothold on the ontological rock face of general relativity; the substantivalist can lay claim to the same object against which relative motion occurs. […] Matters have clearly degenerated […] to the point where this division is no longer doing any real work (2008b, pp. 146-7).

Rickles' idea is that the relationist's relations can be *reduced* to geometrical structure. Similarly, the substantivalist may also claim that this intrinsic structure coincides with their ontological commitments to a substantival spacetime, the 'absolute' coordinates of which may be mapped by using the intrinsic geometrical structure to define a set of 'intrinsic coordinates'. Obviously, as Rickles points out, the relationist might equally well refer to the latter as a material field and 'so continues the interminable tug-of-war' (p. 148). Rickles concludes that the debate between substantivalists and relationists is rendered redundant and that structuralism offers a better alternative: physical systems and spacetime are just different aspects of the same, ontologically fundamental, structure.

It must be stressed that the argument here is certainly not intended to motivate an ontological structuralism of the type championed by Rickles. Rather, it is that the equivalence between spacetime and the gravitational field can be viewed, under a strict interpretation, as there being a single entity, the physical field, that is spatiotemporally structured. The position I am proposing here is to see the relational structure as real, but not ontologically fundamental. Rather it is derivative of an objectively dynamic physical field (the energy-momentum field) that manifests spatiotemporally. I shall describe this as reductionist structuralism, to distinguish it from ontic structuralism.

Conceiving the relationship in this manner provides advantages that help to address some of the conceptual issues encountered in quantum gravity. In the first place, quantum gravity requires there to be a (physical) field that can be the subject of a quantisation procedure. Secondly, a structuralist interpretation permits a better understanding of the requirement of background independence. As noted previously (§ 2.4.3) there is a consensus that resolving the core conceptual issues in quantum gravity relies upon a correct interpretation of the background independence of GTR. The suggestion I propose here is that the underlying problem is not how we interpret background independence, as such, but rather, how we interpret the *equivalence* between spacetime and the gravitational field that gives rise to background independence. Reading the equivalence as a strict equivalence allows one to make more sense of background independence, particularly the apparent dichotomy between 'stage' and 'actor', and the sense in which gravitons both have to *move within* spacetime and *be* spacetime. Such a dichotomy only appears paradoxical if we retain the concept of spacetime as an independently existing, substantival entity, separate from matter or matter fields. If, instead, spacetime is held to be the structure of reality then the paradox falls away: the metaphysically primitive entity is a dynamically existing physical field (matter or mass-energy) that is structured spatiotemporally.

2.7 Conclusion

In Chapter 1 I concluded that the starting point for a theory of presentism, compatible with physical theory, involves the adoption of two foundational premises: P1 and P2. This chapter has argued in support of these premises. The conceptual difficulties encountered in formulating quantum gravity (§ 2.3) support the view that, rather than being metaphysically primitive, time (spacetime) is derivative and equates to the structure of an objectively dynamic reality.

These conceptual difficulties are not unique to emerging theories of quantum gravity (§ 2.3.2), which have yet to be empirically established, but lie within the foundations of GTR itself (§ 2.4.3). Resolving these conceptual difficulties requires an adequate interpretation of background independence within GTR. This is seen as an essential commitment for any theory of quantum gravity. A structural interpretation of the spacetime of GTR provides the best way of understanding background independence (§ 2.6.4).

I have also argued that physics does not support the view that reality is objectively static. In fact, the way in which time is defined within our physical theories provides support for the objective reality of change (§ 2.5). This provides a route for a compatibilist model of presentism which regards (space)time as the structure of an intrinsically dynamic, rather than static, reality.

This approach to time has significant implications for establishing an appropriate metaphysics of change and persistence; this will be pursued in Chapters 4 and 5. Prior to this it is necessary, in the following chapter (Chapter 3) to address the charge that the ontological commitments of presentism are incompatible with physical theory; in particular, the view that ontological parity (and so, eternalism), provides the better metaphysical interpretation of the results of the STR.

CHAPTER 3 – A REJECTION OF ONTOLOGICAL PARITY

3.1 Introduction

Eternalism is the view that all times, objects and events (past, present and future) are equally actual, or real and exist ontologically on a par. Presentism, the view that only present things exist, denies ontological parity. Since only present things exist, the present is ontologically privileged. Eternalism is generally considered to be well-supported by the Special Theory of Relativity (STR). The aim of this chapter is to undermine this claim and to show that the ontological commitments of presentism are compatible with relativistic physics. This compatibility requires the presentist to reject the idea that the present, or 'now', is a unique time and so avoid the commitment to a 3+1 dimensional model of reality. I argue that the presentist, who embraces the intrinsic four-dimensionality of reality, is able to provide a suitable account of relativistic kinematic effects based on the invariance of the speed of light. It is the metaphysical import of the latter fact that provides the key to establishing an appropriate ontology for a compatibilist account of presentism.

I begin (§3.2 & 3.3) by reviewing the paradigmatic arguments to eternalism, known as the 'Rietdijk-Putnam-Penrose' (RPP) arguments and follow this with consideration of a more recent formulation, by Peterson and Silberstein (2010). I argue that both fail. I then assess the merits of the claim that eternalism provides the best metaphysical explanation of relativistic kinematic effects (§3.5). I provide an argument to undermine the key premise on which this claim is based. The remainder of the chapter offers an account of relativistic kinematic effects on behalf of the presentist and concludes with a consideration of the metaphysical import of the STR.

This chapter makes reference to Minkowski spacetime diagrams in describing and analysing some of the arguments. A description of these, and an explanation of the concept of a reference frame, is given in Appendix 1.

3.2 The 'Rietdijk-Putnam-Penrose' (RPP) Arguments to Eternalism from STR

It was not until 1966 that formal arguments[72] were established that attempt to demonstrate that the relativity of simultaneity within the STR leads to eternalism, and this represents the point at which the static view of reality becomes the predominant metaphysical interpretation of our best theories of physics. The first of these was provided by Rietdijk (1966), followed by Putnam (1967) and subsequently reinforced by Penrose (1990). All arrive at their conclusions by way of the same basic argument that I shall summarise below, with reference to a version given by Petkov (2006) in analysing Stein's (1968, 1991) objections.[73]

Figure 3.1 shows three inertial observers (A, B and C) in relative motion:

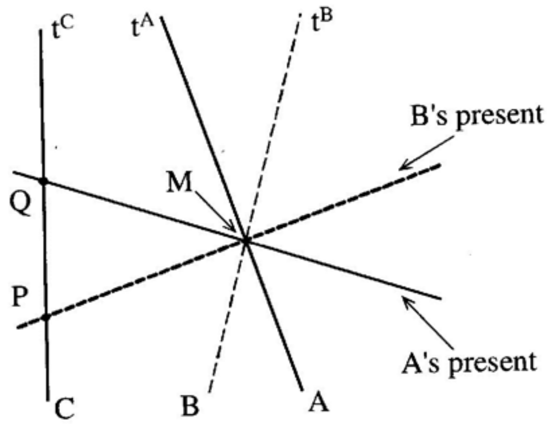


Figure 3.1: *Diagram courtesy of Petkov (2006, p. 211, Fig. 1).*

Observers A and B occupy reference frames R_A and R_B. A and B are, respectively, approaching and receding from stationary observer C and meet at spacetime point M. The events P and Q along the world-line of observer C represent different moments in C's proper time t^C_P and t^C_Q. For example, t^C_P could represent the event of C hitting his thumb with a hammer and t^C_Q, the event of C crying out in pain. Hyperplanes of simultaneity[74] can be drawn for each

[72] Russell (2009) also anticipates these in his 'ABC of Relativity' (first published in 1925), in particular, the implications of the relativity of simultaneity for our time ordering of events and the lack of an unambiguous 'universal time' (pp. 46-48).
[73] Other formulations and discussions of this argument are provided in Savitt (2000), Bourne (2004) and Callender (2008).
[74] Hyperplanes of simultaneity are lines of constant time.

observer, A and B, when they meet at point M; these are given by the lines labelled ‘A’s present’ and ‘B’s present’ respectively. The argument proceeds as follows. For observer B events M and P are simultaneous, therefore events M and P must be equally real, or determinate, for B. In contrast, for observer A, events M and Q are simultaneous and so M and Q are equally real, or determinate, for A. On the assumption that reality is observer-independent and absolute, and since both P and Q are equally real or determinate with respect to point M, the events and moments signified by $t^C{}_P$ and $t^C{}_Q$ must be equally real. This is despite the fact that, for observer C, not only is $t^C{}_Q$ later than $t^C{}_P$ but the latter is causally prior to the former.

The significance of the result becomes even greater when it is appreciated that similar reasoning is applicable to the infinite number of simultaneity hyperplanes that can be drawn through spacetime point M. For all points and events, past, present and future, comprising observer C’s timeline, there exist possible reference frames whereby observers meeting at M will disagree as to which events in their timeline are real as of M. This result is possible only if the following eternalist conclusion holds: all moments of C’s existence have ontological parity, and all events and times (past, present and future) along C’s timeline are equally real (or “coreal”).

This argument may be reconstructed in the following way. The first three premises assume the truth of the STR.

1. Two non-identical reference frames, R_A and R_B, are in relative inertial motion and have origins coincident at spacetime point, M. (Premise)

2. The relation of simultaneity between any two spatially separated events within Minkowski spacetime is reference frame dependent and is defined by three-dimensional hyperplanes orthogonal to the time axis of the reference frame chosen. (Premise)

3. An infinite number of hyperplanes of simultaneity may be drawn through any given spacetime point M depending upon the inertial reference frame adopted. (Premise)

4. Events that are simultaneous within a given reference frame (R) must be equally real ('coreal') or determinate with respect to one another, and equally real or determinate with respect to the observer occupying that reference frame. (Premise)

5. The reality of any event is absolute and observer, or reference frame, independent. (Premise)

6. Coreality is transitive between reference frames. (Premise)

7. Q is simultaneous with M in reference frame R_A and P is simultaneous with M in reference frame R_B. (From 1, 2)

8. Q is real as of M in reference frame R_A and P is real as of M in reference frame R_B. (From 2, 4)

9. Q is absolutely real and P is absolutely real. (From 5, 8)

10. Q is real as of P (From 6, 9)

11. All spacetime points and events are equally real, or determinate, with respect to one another. (From 3, 4, 10)

There are two principal objections in the literature to the RPP formulation of the argument to eternalism. The first targets premise 4 and maintains that simultaneity is not an adequate criterion for reality (and thereby for coreality).[75] The basis of this argument is that the STR dictates that simultaneity is both frame-relative (premise 2) but also a matter of convention.[76] On the (presumably uncontroversial) grounds that reality is absolute and observer-independent, the frame-relative nature of simultaneity counts against it being considered a sufficient criterion for reality.

[75] For example, Stein (1968, 1991) and Bourne (2006, p.172-176).

[76] The conventionality of simultaneity reflects the fact that spacetime is *intrinsically* four-dimensional and so, by choosing to represent this in terms of 3 spatial coordinates and 1 temporal coordinate, the matter of the choice of this fourth (temporal) coordinate is arbitrary and a matter of convention.

The second objection[77] targets the transitivity of coreality (premise 6). The transitivity of coreality requires justification since it is vital in proceeding to the conclusion (11) of eternalism and the ontological parity of all times and events. Sklar (1977, 1985) argues that under the RPP argument, coreality is defined solely in terms of simultaneity (premise 4), yet simultaneity is reference frame dependent within the STR (premise 2) and therefore *not* transitive between reference frames. Consequently, we have good reason to deny the transitivity of the coreality relation:

> Given the relativisation of simultaneity to a reference frame in relativity, anyone who wishes to relate determinate reality to temporal presence must also relativise having reality to a state of motion of an observer. And given the non-transitivity of simultaneity in relativity across observers in differing reference frames, we could easily find our way out of this argument by simply denying that 'having reality for' is a transitive relation (1985, p. 291)

In the following section I describe a reformulation of the argument to eternalism, from Peterson and Silberstein (2010), which aims to address these two standard objections.

3.3 The Peterson-Silberstein Reformulation

Peterson and Silberstein (2010) accept the objections targeted at the RPP formulation of the argument to eternalism, and offer what they regard as a 'new, more conclusive argument in favour' (p. 209) of eternalism. They recognise the need for the coreality relation to be determined by something over and above frame-relative simultaneity, in order to counter both charges: that simultaneity is not an adequate criterion for reality, and that coreality is not shown to be transitive *between* reference frames. Consequently, they propose a re-definition of coreality: two events, A and B, are coreal iff they are simultaneous, *and* they share an identical R-value (pp. 212-214):

[77] For example, Sklar (1977).

Coreality$_{def}$ = frame-relative simultaneity + equivalence of binary R-value

'R-value' is a unary property of any event, such that an event is absolutely real if R=1 and unreal if R=0. According to Peterson and Silberstein, if two events are simultaneous within a given reference frame but both are also absolutely real (i.e., they have an R-value of 1) then they are coreal in *all* reference frames. In such circumstances we are justified in considering their coreality to be transitive (premise 6), and so the argument to eternalism is supported.

The absolute reality of a given event (i.e., the situation where R=1 obtains) depends upon the satisfaction of two, individually necessary and jointly sufficient, criteria which they term 'definiteness' and 'distinctness'. They argue that both are reference frame independent and transitive; the attribution of transitivity to coreality is thereby justified.

In what follows, I first outline Peterson and Silberstein's criteria of definiteness and distinctness (§ 3.3.1). I consider each of the criteria in turn. I argue that definiteness is not transitive under either of the formulations that Peterson and Silberstein provide (§ 3.3.2), and that the sense of definiteness they allude to begs the question at issue between the presentist and eternalist. I then argue that though the criterion of distinctness is transitive, it cannot, on pain of circularity, be a criterion for the reality of events (§ 3.3.3). Neither criterion therefore provides the desired mechanism sufficient to establish the transitivity of coreality without generating a charge of circularity. Consequently, the original objections to the RPP formulation of the argument remain.

3.3.1 The Criteria of Definiteness and Distinctness

Peterson and Silberstein define the concept of *definiteness* with respect to both properties and events, in the following manner:

> A *property* is definite if it has a value that can be 'meaningfully determined' (p. 219).
>
> An *event* is definite if it 'is property-definite with respect to at least one property' (p. 219).

They illustrate the notion of definiteness using examples from quantum mechanics. If a quantum system is in an *eigenstate* of x-spin, then all measurements on the system yield the same value of x-spin and the system can be said to be 'property-definite' with respect to spin in the x-direction. In contrast, if the quantum system is in a *superposition* of x-spin states, different measurements will yield different (probabilistically describable) results with respect to x-spin. In this case the system is 'property-indefinite' with respect to x-spin. So, for Peterson and Silberstein, an event is definite if it has at least one property to which we can assign a determinate value (in the widest sense of value), for example, value of spin in the x-direction.

The second necessary condition on the reality of an event is *distinctness*. The distinctness of an event is described as follows:

> a distinct event must be in some way different from other distinct events (a la Leibniz, call it the discernibility of non-identicals) […] two completely indistinguishable events cannot be numerically distinct. (p. 220)

Distinctness is therefore given in terms of discernibility.

3.3.2 Evaluating the Criterion of Definiteness

I argue that Peterson and Silberstein construe definiteness in two separate ways. The second formulation of definiteness begs the question of the reality of an event, and under neither construal is the criterion of definiteness transitive. The addition of the criterion of definiteness in their definition of coreality therefore fails to secure the transitivity of coreality in the manner required to reach the conclusion of eternalism.

Definiteness is defined by Peterson and Silberstein, in general terms, as the possession of a determinate value (2010, p. 219). However, their argument for the transitivity of definiteness relies upon an analogy they draw between possession of a determinate value and the concept of relativistic invariance, and this leads to an additional formulation of definiteness.

In arguing for the transitivity of definiteness, the authors begin by proposing that 'any relativistically invariant relational property must be transitive across all reference frames' (p. 223). A relativistically invariant property is one upon which all observers, in all inertial reference frames, can agree. The value assigned to the property by an observer in one reference frame will be the same as the value assigned by an observer in a different inertial frame. Examples include the speed of light, *c*, and the spacetime interval, ds^2, between any two events.

For the purposes of their argument, Peterson and Silberstein propose that one such relativistically invariant property is 'the number of events that occur' (p.224). On the grounds that this property is analogous to definiteness, they claim that the transitivity of the latter is similarly justified:

> All observers, no matter their frame, will agree on the number of events that occur. Thus, no matter what frame an observer is in, it will never be the case that she will see an event take place that another observer does or could not see. Though observers may disagree about some of the properties of an event, no observer will see a "novel" event; that is, there is no event simpliciter that one can only see if one is in a certain reference frame. This means that the very existence, the very definiteness of an event-as-such must be a relativistic invariant, and thus as per our pre-established criterion, definiteness must be transitive across frames. (p. 224)

'The number of events that occur' is provided as a paradigmatic example of definiteness which is construed, in more general terms, as the possession of some determinate value: an event is definite if it has more than one property to which a determinate value can be assigned, or 'meaningfully determined'. Defined in this way definiteness is a monadic property and, if so, it cannot also be transitive on the grounds that transitivity is applicable only to relations. A relational property is one possessed by a particular in virtue of the relations it bears to other things. As such, it is not clear how either 'the number of events that occur', or the property of definiteness, *could* be construed as relational (irrespective of whether they might be considered relativistically-invariant) and, if such properties are not relational then they cannot be transitive.

Nonetheless, the argument they give suggests that it is on the grounds of the *relativistic invariance* of 'the number of events that occur' that, by analogy, definiteness should be considered transitive between reference frames. It appears that it is not 'transitivity', in the normal sense of the term, that is being appealed to here. Rather, it is the property of being *invariant* between reference frames that is sought. If definiteness, as a necessary criterion on reality, is invariant between reference frames, in other words, if its applicability is agreed upon by all observers then the event is absolutely real, for all observers. In this case, the transitivity, or otherwise, of definiteness is irrelevant in moving to the conclusion of eternalism. If we allow Peterson and Silberstein this modified line of argument then we need to assess whether the property of definiteness, as exemplified by 'the number of events that occur', is indeed relativistically invariant. And in this case it needs to be clarified exactly which sense of 'occur' it is that is being appealed to.

On one reading of 'occur' it is just not the case that 'all observers, no matter their frame, will agree on the number of events that occur' (*Ibid.,* p.224). As seen in the description of the RPP arguments (§ 3.2), observers in relative motion *do* disagree on what events have occurred, indeed this is the primary motivation of the argument to eternalism. Penrose (1990) describes the following scenario:

> The events on the Andromeda galaxy [...] judged by the two people to be simultaneous with the moment that they pass one another could amount to a difference of several days [...]. For one of the people, the space fleet launched with the intent to wipe out life on the planet Earth is already on its way; while for the other, the very decision about whether or not to launch that fleet has not yet even been made! (pp. 260-261)

The relativity of simultaneity suggests that different observers, within different reference frames, *will* disagree as to which events have occurred. This sense of 'occur' is one that equates with 'simultaneous with' and, as such, is reference-frame dependent. Since it is reference-frame dependent it is neither relativistically invariant nor transitive.

In the paragraph quoted above (p. 224), however, it becomes clear that Peterson and Silberstein allude to another sense of occurrence in describing 'the number of events that occur' as exemplifying definiteness. They make reference to the 'event simpliciter' and this suggests a sense of occurrence independent of any particular reference frame: they state that the 'very definiteness' of an event is its 'very existence', about which no observers could disagree. Here the definiteness of an event is construed in terms of its *absolute* occurrence, or its absolute existence, independent of any particular reference frame. This rendition of definiteness appeals to a notion of existence which all commentators of a realist bent (presentist and eternalist alike) would presumably accept: existence is something both observer and reference frame independent.

Nonetheless, if it is *this* notion of occurrence, instead, that is at the core of their alternative concept of definiteness then it begs the question central to the dispute between the presentist and the eternalist. For Peterson and Silberstein (§ 3.3), definiteness is intended to be a necessary criterion on the absolute reality of an event, one that determines that R=1. If so such a criterion cannot be defined in terms of the 'very existence' or occurrence of the event independent of reference frame, on pain of circularity. It is the (absolute) reality of a given event, or particular, that is precisely at issue between the presentist and the eternalist.

It was noted above that the transitivity, or otherwise, of definiteness is irrelevant if definiteness is given in terms of frame-invariance. Aside from issues of circularity, it is worth stating that, contrary to the argument made by Peterson and Silberstein, this second concept of definiteness is also not transitive. As with the initial construal of definiteness (as possession of a determinate value), it is not transitive on the grounds that it is not a relational property. The absolute occurrence of an event *qua* absolute is a property independent of the existence of anything else, and so independent from any relations it might bear to anything else.

In summary, Peterson and Silberstein construe definiteness in one of two ways: as the possession of a determinate value or in terms of reference-frame independent existence. Under neither construal is definiteness transitive and, if it is not transitive, it cannot be employed to justify the transitivity of their reformulation of coreality. In addition, the second formulation of definiteness cannot be used as a criterion on the reality of events without circularity.

3.3.3 Evaluating the Criterion of Distinctness

Peterson and Silberstein describe the criterion of distinctness in terms of numerical distinctness, or 'discernibility'. At first glance then, distinctness, as an intrinsic property of a given event is not a relational property and so, on those grounds, cannot be transitive.

However, the authors elaborate further on the nature of distinctness, once again with reference to relativistic invariance, in this case the invariance of the spacetime interval (ds^2) between events:

> Because the interval between events is an invariant, it is always possible for observers in different frames to distinguish between different space-time events in a consistent manner. Because of this, no observer will confuse two events that are seen as distinct in another frame. (p. 224)

Their argument is in two parts. First, they claim that the distinctness of any two events is provided for by the invariant spacetime interval between them. This seems reasonable since they define distinctness in terms of discernibility: the invariant spacetime interval between any two events means that all observers in all inertial frames will consider them to be distinct events and will agree on the extent of the interval that separates them. Second, since the invariant spacetime interval is transitive between reference frames then so, by analogy, is distinctness. Distinctness, seen in terms of 'being invariantly spacetime separated from', is both a relational property and one to which transitivity applies, and so it can be agreed that distinctness is transitive across reference frames.

Although distinctness is transitive, as with the criterion of definiteness, I argue that distinctness begs the question at issue between the presentist and eternalist. There cannot *be* an invariant spacetime interval between two events unless those events occur. On the grounds that relations imply the existence of their relata, the existence of an invariant spacetime interval between events depends upon the prior reality of those events. If distinctness is a relational property that relates two events, then for the relation to exist the two events themselves must exist. And if distinctness requires that both events exist, it cannot, on pain of circularity, be a criterion for the reality of those events.

3.4 A Summary of the Problems with the Argument to Eternalism

It is useful to reiterate the purpose of the criteria of definiteness and distinctness in Peterson and Silberstein's modified argument to eternalism.

The criticism of the original (RPP formulation) of the argument is twofold. First, simultaneity is not an adequate criterion to determine the coreality of any two events *within* a reference frame: the simultaneity of two events within a single reference frame is not sufficient for an observer within that frame to claim that they are both real. In addition, in accordance with the STR, simultaneity is not transitive between reference frames (it is only transitive within a given reference frame). Therefore, even if simultaneity *were* an adequate criterion of the coreality of two events in one reference frame, we are not justified in moving to the reference frame of a different observer and asserting that those two events are coreal for them.

In order to address the first criticism, Peterson and Silberstein recognise that the coreality of two events within a given reference frame (R_0) must be something more than their simultaneity. In order to be coreal, events must also share an R-value equal to 1 (§ 3.3), where an R-value of 1 indicates that the event is absolutely real. Definiteness and distinctness are proposed as necessary and sufficient criteria for an event to possess R=1, and so be absolutely real, within a given reference frame. In order for the coreality of any two events, within that frame, to be *transitive* and so coreal for observers in all other reference frames, definiteness and distinctness must also be shown to be transitive. It is transitivity that permits the inference that two events that are coreal (or absolutely real) within one reference frame (R_0), must also be coreal for all observers, in all possible reference frames.[78] It is this step that leads to the conclusion of eternalism.

I have argued that definiteness cannot be transitive, under either formulation provided by Peterson and Silberstein. In addition, under their second formulation, definiteness assumes the reality of the event to which it applies and so is redundant as an addition to simultaneity in the re-definition of coreality. I also argue that, though distinctness is transitive between reference frames it also assumes the reality of the events to which it is applied, it therefore fails to supplement the notion of coreality with anything over and above frame-relative simultaneity. Since frame-relative simultaneity is non-transitive, the original objection to the RPP formulation of the argument to eternalism stands.

Nonetheless, the argument might be considered to have merit if it turns out that the truth of the STR provides good reason to suggest that eternalism (and its associated static view of reality) is significantly better supported than rival metaphysical theories. The following section critically assesses the extent to which eternalism (as the ontological parity of all events) provides the 'best fit' in terms of a metaphysics of reality and finds it to be lacking support from the STR.

3.5 Eternalism as Inference to the Best Explanation (IBE)

Despite the shortcomings of the argument to eternalism from the STR, it remains the case that eternalism is generally considered[79] the metaphysical theory best placed to provide an adequate explanation of the relativistic kinematic effects of the STR (such as length contraction and time dilation). The

[78] More accurately, 'all possible reference frames' means all reference frames potentially coincident with the origin of R_0.
[79] See, for example, Balashov and Janssen (2003), Petkov (2006) and Norton (2008).

argument is that unless we accept the ontological parity of all actual events, we struggle to account for the empirically verifiable results of the STR.

The standard account of the utility of eternalism in explaining relativistic kinematic effects will be illustrated using the argument in Petkov (2006). For Petkov, relativistic length contraction (for example, that of a rod) is only possible if the 'worldtube of the rod is a real four-dimensional object, which means that the rod exists equally at all moments of its history' (p.215). Petkov refers to two observers in relative motion (A and B), who meet at point M. The rod (L) is at rest in A's reference frame. He illustrates this as follows:

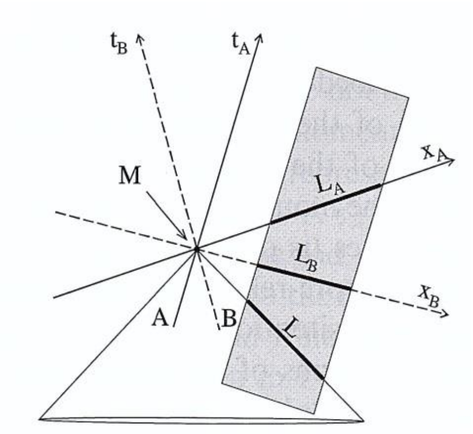


Figure 3.2 *– The world-tube of a rod at rest in observer A's reference frame.*
Diagram courtesy of Petkov (2006, p. 218, Fig. 4).

Observer B, who is in relative motion with respect to A and the rod, measures the rod to have a contracted length L_B such that $L_B < L_A$ (where L_A is the length of the rod at rest in A's reference frame). Petkov's argument is as follows:

> A and B have different three-dimensional rods, but they see the same three-dimensional cross-section L which, however, cannot be regarded as a three-dimensional rod since all parts of a three-dimensional object exist simultaneously at one moment (the moment 'now')…It follows from here that it is not possible to interpret the length contraction in a sense that it is the same three-dimensional rod that exists for A and B, but they see it differently…The fact that A and B have different three-dimensional rods means that the two rods of lengths L_A and L_B, respectively, belong to the presents of A and B that correspond to event M. (2006, p. 218)

Petkov concludes:

> A's present rod also contains parts of B's past, present, and future rod. This would not be possible if the rod did not exist equally in its past, present and future. Therefore, A and B conclude that their experiment has a profound physical meaning – it proves that all physical objects are extended in time, which means that they are four-dimensional (2006, pp. 220-1).

Hales and Johnson (2003) provide an argument based on a similar reasoning, using the example of a relativistic train, though the force of their argument is to argue for perdurantism, over endurantism, as the 'best fit' with the empirical facts of the STR.[80] Both Petkov, and Hales and Johnson, state the argument in tensed terms, by suggesting that the three-dimensional rod measured by each observer contains parts that may be attributed to the past and the future of the other observer. The generic IBE argument to eternalism from length contraction may be reconstructed as follows:

1. The lifetime of a 3D rod (its past, present and future) can be shown as a 4D world-tube on a Minkowski spacetime diagram. (Premise)

2. Each observer's measurement of the rod is equally valid as a description of reality at the time of measurement (the principle of relativity or 'no privileged observers' requirement). (Premise)

3. Each observer measures a different 3D cross-section of the rod's 4D world-tube at the same time t_0. (Premise)

4. If an entity can be measured at time t_0, then the entity exists at time t_0 (Ontological Assumption). (Premise)

5. The existence of parts of an object that are past and future with respect to a given present time, relative to an observer's reference frame, is best

[80] The question of whether eternalism entails perdurantism is a separate debate and is considered, for example, by Merricks (1995).

explained by positing the co-existence of those past, present and future parts. (Premise)

6. Observer B's 3D cross-section contains parts of the rod that are past with respect to A's 3D cross-section and parts that are future with respect to A's 3D cross-section. (From 1, 3)

7. Each observer's measured 3D cross-section exists at the time t_0 of measurement. (From 2, 3, 4)

8. Eternalism (the coexistence of the past, present and future 3D cross-sections of the rod) provides the best metaphysical explanation of the length contraction results of the STR. (From 5, 6, 7)

Although there are possible arguments that could be suggested to undermine premise 2, these will not be pursued here and the principle of relativity is accepted.[81] The key premises that allow the argument to eternalism to go through are premises 3 and 4. In the following sections I provide arguments to reject these premises, consequently the conclusion that eternalism provides the best metaphysical explanation is false.

3.5.1 The Grounds for Rejecting Premise 3

Premise 3 states that each observer measures a different 3D cross-section of the rod's 4D world-tube when they meet at point M, the point of measurement. I argue here that premise 3 is false and that both observers measure the *same* 3D cross-section of the rod's world-tube.

In the following example I shall use the convention for Minkowski diagrams where the unprimed axes are orthogonal and represent the reference frame at rest (S) with respect to the object considered, and primed axes represent the

[81] For example, the following alternatives to premise 2 might be proposed. Firstly, that one observer makes the objectively 'correct' measurement, the other observer's measurement is false. However, this implies there is no empirical method of determining the preferred frame and it is considered here that the positing of in-principle unobservable preferred frames should be rejected on the grounds that we have no reason to think that there is such a preferred frame and no explanation for the hypothesis that there might be. A second alternative might claim that reality is 'fractured' and relative to each observer's reference frame. Against this it is suggested that a theory positing a 'fractured' reality should be rejected in favour of one that posits a single, unified reality on the grounds that the latter is more explanatorily elegant and powerful.

reference frame (S') in relative motion. I also centre the axes at the mid-point of the rod since this makes the example easier to understand.

The following scenario is considered.

Figure 3.3 shows rod, R, at rest in frame S (x_A, t_A) with Alice standing at the midpoint (x_0t_0). Measurement of the length of the rod requires a measurement of the position of each end of the rod at the same time (t_0) within the rest frame, R, of the rod.[82] In order to do this, Alice arranges for a light pulse to emit simultaneously (with respect to x_0t_0 in frame S) from either end of R at t_0.[83] A while later she receives the light from both ends of the rod, at point M (x_0t_1), and thereby calculates the length of the rod to be Δx_A.

Bob, in frame S' (x'_B, t'_B), travelling with relative velocity, *v,* with respect to S, is coincident with Alice and the mid-point of the rod at point M. He too measures the rod at M but finds it to have a contracted length $\Delta x'_B < \Delta x_A$.[84]

[82] Note that Alice's reference frame and the rest frame of the rod, R, are identical.
[83] Using an appropriate synchronisation procedure.
[84] It should be noted that, contrary to appearances on the diagram, line $\Delta x'_B$ is, geometrically, less than line Δx_A because the scale, representing unit distance, is not the same along the different axes x_A and x'_B. Distances in Minkowski spacetime are not given by the Euclidean line element, rather by the spacetime interval $\Delta s^2 = \Delta x^2 - (c\Delta t)^2$.

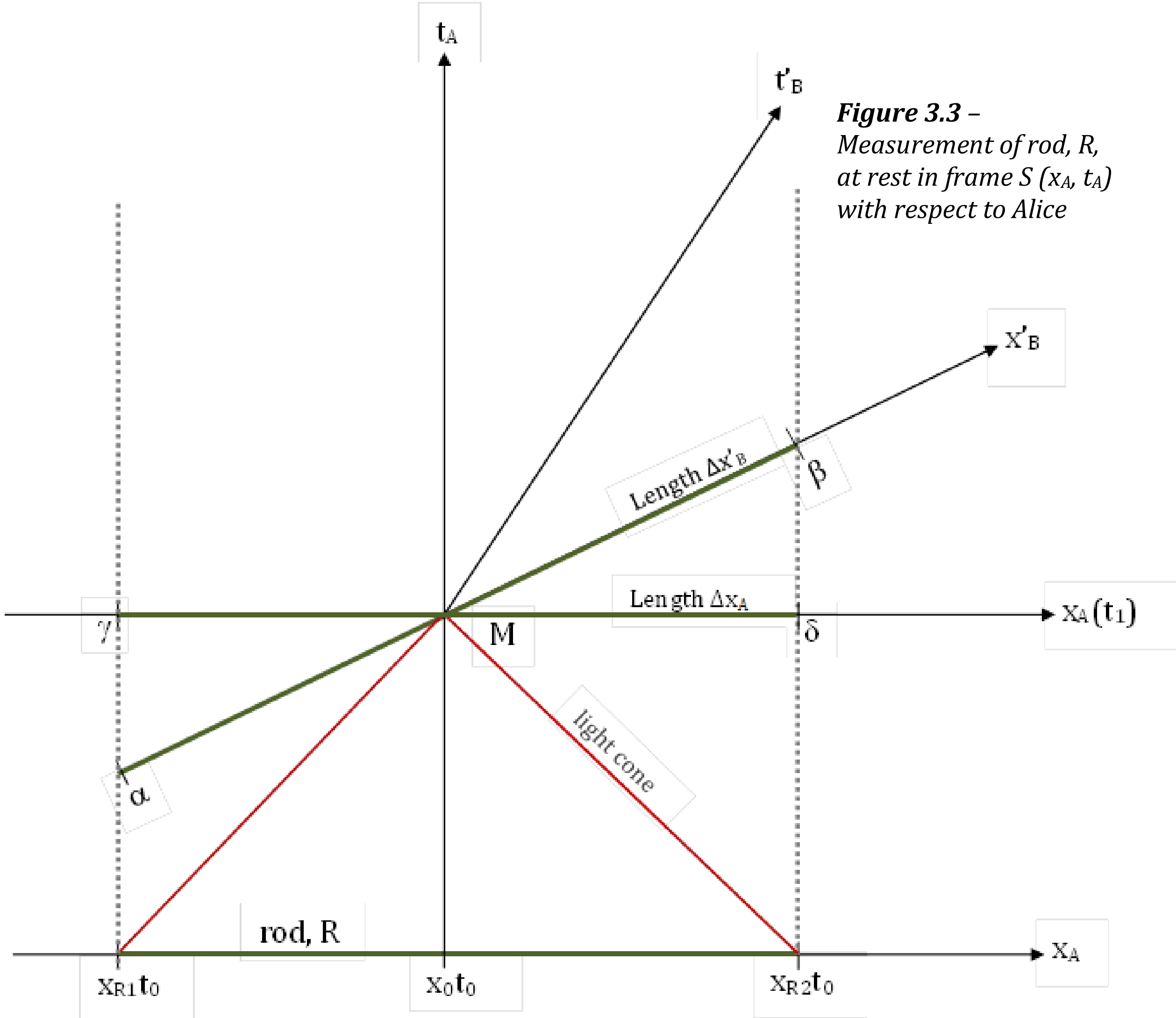


Figure 3.3 – *Measurement of rod, R, at rest in frame S (x_A, t_A) with respect to Alice*

In what follows, there are two points that need to be emphasised about the nature of measurement within the STR:

1. Any measurement requires the transmission and receipt of light (or other) signals.
2. The speed of light is finite (it takes time to propagate); there is therefore no instantaneous signalling. This means that what is measured is always *past* with respect to the observers making the measurement.

Both Alice and Bob measure the rod at M using the light signals received, at that point, from either end (the paths of the light signals are indicated by the light cone in the diagram). As a consequence of the finite speed of light, and the fact that it takes time to propagate, what *both* observers measure at point M is the rod, R, *as it existed* between spacetime points $x_{R1}t_0$ and $x_{R2}t_0$ (the points at which the light was emitted). It follows that what each observer measures, at spacetime point M, is the *same* 3D cross-section of the rod (the rod that existed between $x_{R1}t_0$ - $x_{R2}t_0$ in its rest frame) and not *different* 3D cross-sections. Premise 3 is therefore false.

Nonetheless, although Alice and Bob measure the same 3D cross-section, their measurements assign a different length to that cross-section and the reason for this is explained in §3.6.3.

3.5.2 The Grounds for Rejecting Premise 4

Premise 4 states that 'if an entity can be measured at t_0, then the entity exists at t_0'. Although this seems intuitively appealing, this is not true within the STR. The explanation for this also turns on what it means to make a measurement within the theory. As noted above, any measurement relies upon the transmission and receipt of some signal.

In the scenario described, both Alice and Bob rely upon the propagation of light signals from either end of the rod (existing in the interval $x_{R1}t_0$ - $x_{R2}t_0$) in order to make their respective measurements. As already noted, the finite speed of light means that the 3D cross-section of the rod that they both measure at M is the 3D rod *as it previously existed* in the spatiotemporal interval $x_{R1}t_0$ - $x_{R2}t_0$. For this reason, a distinction necessarily arises between what *exists* at a point of measurement (M) and what is *measured* at that point. What *exists* at the single spacetime point, M, is Alice, Bob, the mid-point of the rod (x_0t_1) and the two light signals, that converge at that point, from either end of the rod. What is *measured* at point M, by way of the converging light signals, is the rod, R, as it previously existed between points $x_{R1}t_0$ - $x_{R2}t_0$. Since any measurement requires the propagation of light signals from an object to the point of measurement, the object measured does not necessarily exist at the point of measurement. The following scenario makes this clearer.

3.5.2.1 *The Disintegrating Rod Argument*

In Figure 3.3 it was implicitly assumed that all parts of the rod existing in the interval $x_{R1}t_0$ -$x_{R2}t_0$ continue to exist between t_0 and t_1, in its rest frame. This is, of course, not necessarily the case. An equally consistent scenario can be modelled and represented using the same Minkowski diagram.

Suppose that, at the point at which Alice arranges for a light pulse to emit simultaneously from either end of R, the mechanism she employs also causes a progressive disintegration of the rod from each end; this destructive influence also propagates at the speed of light. By the time (t_1) that Alice meets Bob at M the rod has disintegrated to a point particle occupying M (x_0t_1). In this case the world-tube of the rod is not a 'tube' but is coincident with the light cone since the rod disintegrates at the speed of light, as shown in Figure 3.4.

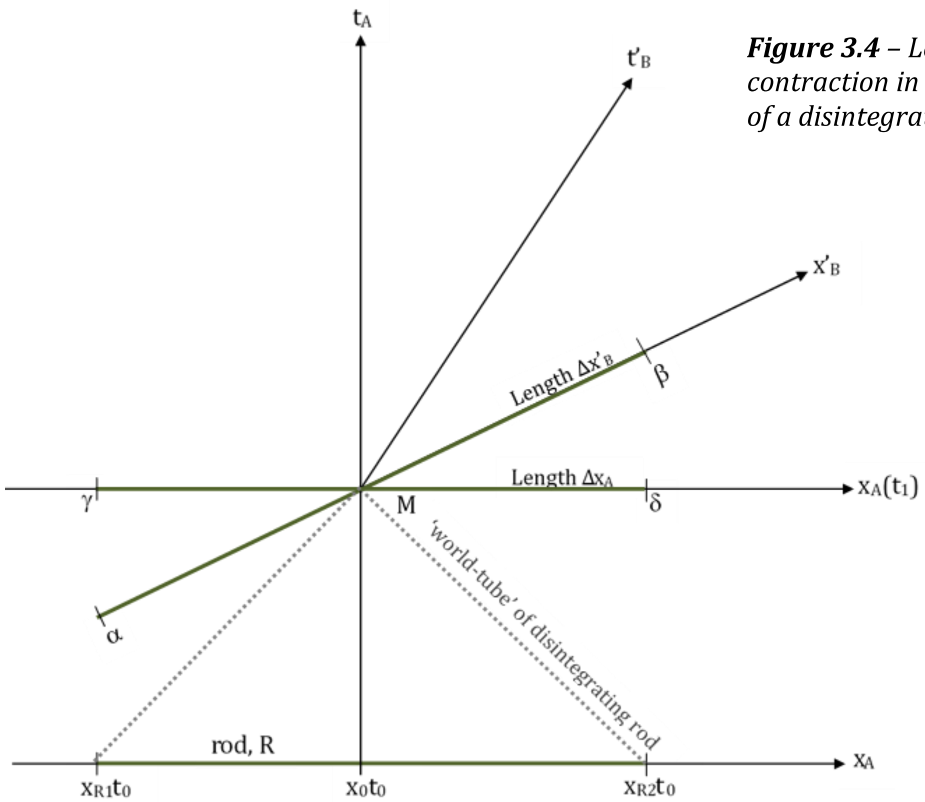


Figure 3.4 *– Length contraction in the case of a disintegrating rod*

On the assumption that Alice and Bob are restricted to occupying the single spacetime point, M, they are none the wiser as to the disintegration of the rod. Nevertheless, at M, Alice and Bob, as in the previous scenario, receive the light signals emitted from each end of the rod (that existed at $x_{R1}t_0$ - $x_{R2}t_0$) and so perform their respective calculations. The respective lengths they assign to the rod will, nonetheless, *still be given* by the length intervals Δx_A and $\Delta x'_B$ (shown in Figure 3.4), where $\Delta x'_B < \Delta x_A$, since these calculations depend only on the speed of light and the respective coordinate axes. These remain equally valid descriptions of the rod as it previously existed at $x_{R1}t_0$ - $x_{R2}t_0$, even though the rod, now at M, exists only as a point particle.

This example reveals how two ontologically divergent scenarios can be modelled by the *same* Minkowski diagram. It can be concluded from this that the intervals Δx_A and $\Delta x'_B$, although equivalent spatiotemporal descriptions of the rod previously existing at $x_{R1}t_0$ - $x_{R2}t_0$, imply nothing about the ontological status of the rod at M, or indeed at any point subsequent to M. This example shows that premise 4 is not necessarily true, the rod that is *measured at* M does not necessarily *exist* at that point.

3.5.3 Why the Argument to Eternalism Fails

It has been argued that both premises 3 and 4, in the IBE argument to eternalism, are false. Each observer measures the same 3D cross-section of the rod as it previously existed and the fact that they assign different spatiotemporal descriptions to the rod (for the observer in relative motion the length is contracted) implies nothing as to the existential status of the rod at the point of measurement. Nonetheless, there is a need to explain why it is that the conflicting descriptions of the length, both of which are equally valid (from the principle of relativity), generate the erroneous conclusion that they correspond to different 3D cross-sections of the rod's 4D world-tube and, further, that Bob's 3D cross-section contains parts of the rod that are past and future with respect to Alice.

I first outline the reasoning in support of the conclusion that Bob's 3D cross-section contains parts of the rod that are past and future with respect to Alice. I then argue that this relies upon an assumption that has no basis in the STR.

The lifetime of the 4D rod can be denoted by a 'world-tube' on a spacetime diagram; this is indicated in Figure 3.5 by the grey hashed lines that proceed from either end of the rod and run parallel to the t_A axis. Assuming that the whole rod (originating in the spatiotemporal interval $x_{R1}t_0$ - $x_{R2}t_0$) continues to exist, rather than disintegrating, then the mid-point of the rod would move along a line perpendicular to x_0t_0 up to point M (x_0t_1); in doing so it traces a ‘tube’ in Minkowski spacetime. This world-tube represents the causal history of the 4D object, resolved into separate temporal and spatial coordinates, and is *only* defined relative to the reference frame at rest with respect to the object described.

From Figure 3.5 it can be seen that the 3+1D coordinate descriptions assigned by each observer (at M) appear to coincide with different 3D cross-sections of the rod’s world-tube, parts of which occur in the future and the past relative to the observer’s meeting point, M. Alice describes the rod as occupying the interval γt_1 - δt_1, with respect to point M, whereas Bob describes the rod as occupying the interval $\alpha t'_0$ - $\beta t'_0$, with respect to point M. Considered as cross-sections through the rod’s world-tube this appears to suggest that, for Bob, one end of the rod exists in its past (at spacetime point $\alpha t'_0$) and the other end in its future (at spacetime point $\beta t'_0$).

The inference that each observer’s 3+1D description corresponds with a different existent proper part of the rod’s 4D world-tube requires the assumption that there is an absolute coincidence between the spacetime coordinates in the different observer’s reference frames. The world-tube of the rod is defined *only* with respect to its rest frame (Alice’s reference frame); consequently, in order that the 3+1D description assigned by Bob (in his reference frame) *is* a 3D slice through the rod’s world-tube (defined in Alice’s reference frame) there must be a relation of identity between the coordinate points defining the position of the rod in Bob’s reference frame and the coordinate points defining the world-tube of the rod in Alice’s reference frame.

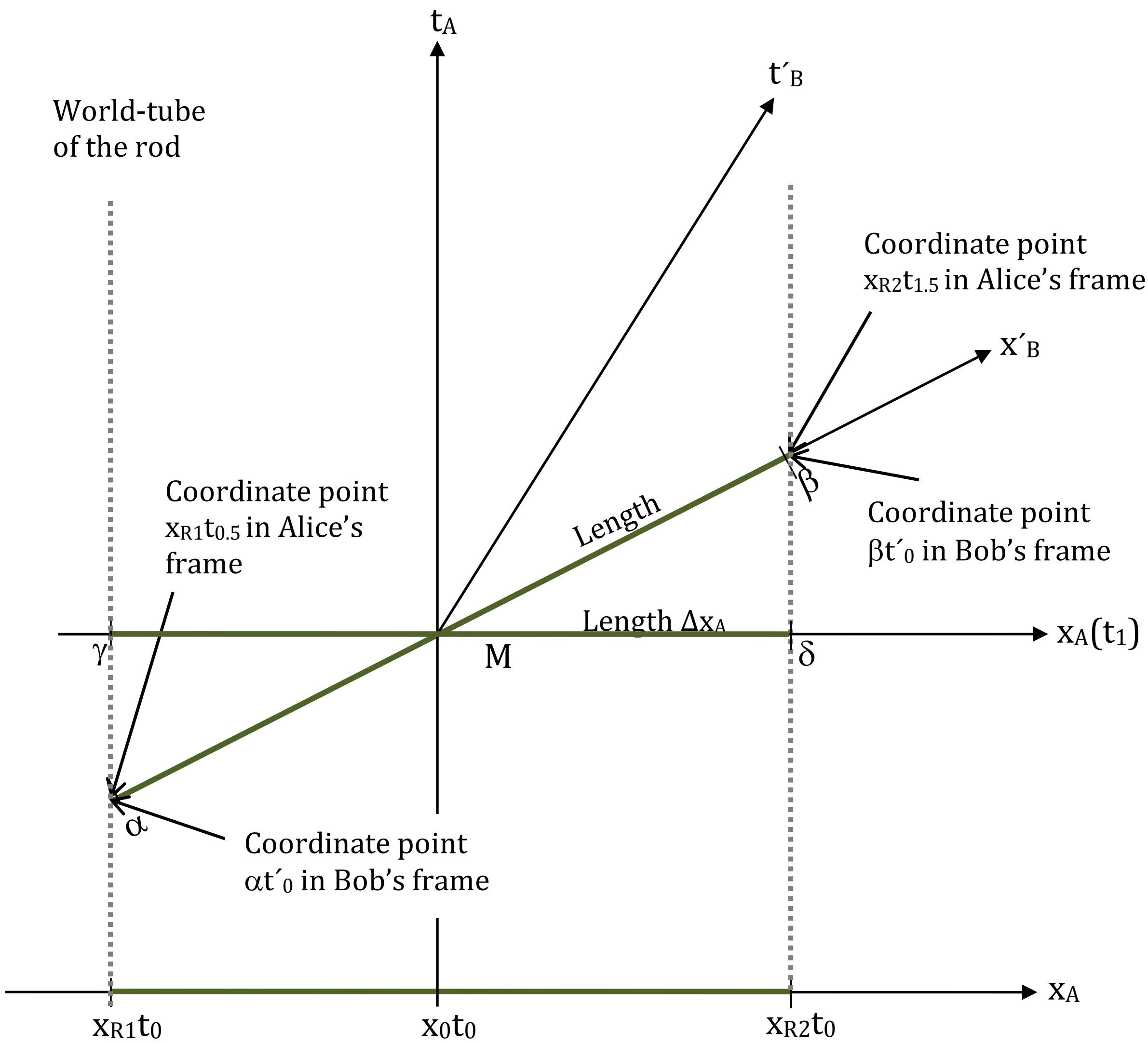


Figure 3.5 *– Coincidence of spacetime coordinates in reference frames S and S´*

In particular, the requirement for an identity between the coordinates means that coordinate point $\alpha t'_0$, in Bob's reference frame, is absolutely coincident with a coordinate point ($x_{R1}t_{0.5}$) in Alice's reference frame and similarly that coordinate point $\beta t'_0$ (Bob's frame) is absolutely coincident with coordinate point, $x_{R2}t_{1.5}$ (Alice's frame). I provide two reasons to undermine this assumption of absolute coincidence.

The first argument is provided by the example of the disintegrating rod (§3.5.2.1). The premise that objects exist as four-dimensional world-tubes in Minkowski spacetime provides an intuitive and visually persuasive explanation of length contraction. The discrepancy in the spatial intervals measured by each observer coincide with different three-dimensional cross-sections through the rod's four-dimensional world-tube. However, the case of the disintegrating rod reveals that it *cannot* be the case (however visually persuasive) that there is an identity between the coordinate points on each observer's (spatial) coordinate axis and spacetime points at which the rod exists when measured at M. In this case, the length intervals assigned by each observer do *not* coincide with the world-tube of the rod (Figure 3.4); the 'world-tube' of the rapidly disintegrating rod is given by a *cone* on the spacetime diagram (coincident with the light cone defining the path of light emitted from each end of the rod). If there is no correspondence in this case, between the measurements of length by both observers and a cross-section through the rod's world-tube, then there is no justification is assuming such a correspondence in the case where the whole length of the rod continues to exist. The different measurements of length obtained by the two observers therefore do not correspond with the present existence (at the point of measurement) of future and past spatial parts of the rod. Rather, the observers' measured length intervals are two, equally valid, spatiotemporal *descriptions* of the rod as it *existed* (at $x_{R1}t_0$ - $x_{R2}t_0$ in its rest frame) *prior* to the meeting of Alice and Bob.

The disintegrating rod argument makes it clear that there is a distinction to be made between coordinate points (which provide different, equally valid, spatiotemporal *descriptions*) and spacetime points (as points at which objects and events exist). It is pertinent here, as Maudlin (2012, p.26) notes to heed Einstein's warning that coordinates need not have any direct *physical* significance. The Minkowski diagram is equally well regarded as a heuristic tool: i.e., as a geometric representation of reality employed to predict the different measurement results of different observers.

This leads to a second argument against the absolute coincidence of the measurement coordinates and the spacetime points defining the four-dimensional world-tube of the rod.

In order that coordinate points within different reference frames are absolutely coincident within Minkowski spacetime, the point of coincidence has to be defined by some event common to both observers (or reference frames). This common event thereby defines a spacetime point. In the case of Alice and Bob such an event is their meeting at point M. This coincidence event, an event common to both their causal histories, permits the equation $x_0t_1 \equiv x'_0t'_0$, which defines point M and allows the origins of their respective reference frames to coincide. In the example illustrated, though, there is no other such event, common to both Alice and Bob. In particular, there is no common event that permits an equation between coordinate point $\alpha t'_0$, in Bob's reference frame, and coordinate point $x_{R1}t_{0.5}$, in Alice's frame. A similar argument holds in respect of the coordinate points $\beta t'_0$ (Bob) and $x_{R2}t_{1.5}$ (Alice). As such, there is nothing to justify the assertion of an identity between these coordinate points in the separate reference frames. Since the world-tube of the rod is defined only with respect to its rest frame (Alice's reference frame) it cannot be inferred that the coordinate point, $\alpha t'_0$, in Bob's reference frame constitutes part of the rod's world-tube, in other words, that it is a spacetime point occupied by the rod (and associated with a previous moment in time). An analogous argument applies to the inference that coordinate point $\beta t'_0$ (in Bob's reference frame) lies on the world-tube of the rod and so comprises a spacetime point in the causal future of the rod.

The eternalist explanation of relativistic length contraction, in terms of the existence of objects as four-dimensional world-tubes, although visually persuasive, is false. It cannot be inferred that Bob's assignment of 3+1D coordinates on measurement of the rod corresponds with parts of the rod's 4D world-tube that are past and future with respect to Alice.

3.6 A Compatible Presentist Approach

In the remainder of this chapter I argue for the compatibility of presentism with the STR and propose how a compatibilist model of presentism should account for relativistic kinematic effects. I end with a reflection on the metaphysical import of the STR and this provides the key to establishing a suitable ontological model for a compatibilist presentism.

3.6.1 Abandoning 3+1D Reality

In this, and the following section, I argue that the presentist should accept the intrinsically four-dimensional nature of reality, and that this is perfectly compatible with presentism. In § 3.6.3, I use this feature of reality to provide an account of relativistic effects on behalf of the presentist.

It is standardly assumed[85] that the presentist, who also subscribes to the 'thesis of objective passage' (premise P1, Chapter 1, § 1.6), is committed to absolute simultaneity and describing reality in 3+1 dimensional terms. Nonetheless, as discussed in Chapter 1, serious problems face the presentist when objective passage is formulated as *temporal* passage, as a flow of time, or with respect to time; it is this notion of passage that relies upon absolute simultaneity. Chapter 1 concludes that a compatibilist model of presentism requires a mechanism for internalising the tense-indicative, dynamic aspects of reality, and so formulating them independently of time. This means that the requirement for absolute simultaneity should be abandoned; it also means that the present, or 'now', should not be seen as a unique, or indeed any, *time*.[86]

Aside from the McTaggart-style problems of contradiction and infinite regress, the search for a unique plane of simultaneity, within relativistic spacetime, still encounters the thorny metaphysical issue of Callender's (2008) 'coordination problem' (§1.4.3). If this does not provide reason enough for the presentist to eschew all talk of absolute simultaneity, there is a further motivation. It will be recalled from the critical analysis of the arguments to eternalism (§3.2, 3.3) that it is the appeal to simultaneity, as sufficient criterion for the coreality of events, that underpins the arguments. If the principle objection to these arguments is to be upheld then, on the grounds of consistency, simultaneity cannot also be employed by the presentist as providing the ontological privilege of the present.

For all these reasons I believe the presentist should seek to reconcile their position with the fact that reality is intrinsically four-dimensional. In the

[85] I refer the reader back to footnote 22, §1.4.3 where an overview is given of commentators who maintain this position.

[86] The way in which the present can be formulated independently of any reference to time will be discussed in Chapter 4.

following section I describe what it means to exist four-dimensionally and why this is not at odds with the commitments of the presentist.

3.6.2 Existing Four-Dimensionally

The term 'four dimensionalism' is often employed with reference to perdurantism and the corresponding static view of reality (e.g. Sider, 1997, 2001). As such there is an implicit bias against the compatibility of presentism with acceptance that reality is four-dimensional. However, if the term is used in line with its meaning within the STR there is no incompatibility.

Within classical, Newton spacetime it is possible to represent the complete lifetime of an object as a four-dimensional world-tube, and so the fact that objects can be represented by four-dimensional world-tubes within the STR is nothing new. Objects also exist four-dimensionally within classical spacetime. Nonetheless, there is a difference between what it means for objects to exist four-dimensionally under Newtonian spacetime and within the spacetime of the STR (Minkowski spacetime). Specifically, in the former there is no inter-dependency between the three spatial and the one temporal dimension, they are completely separate. Consequently, existing four-dimensionally within Newtonian spacetime means that all observers, regardless of their relative velocity, will assign the same spatial and temporal intervals between objects and events, they are fixed for all observers. If spatial and temporal intervals are fixed, there will be no discrepancies in these intervals between observers in relative motion. In particular, there will be no length contraction and no time dilation.

This is different under the STR. The spacetime of the STR is *intrinsically* four-dimensional, in the sense that the spatial and temporal intervals are inseparably linked. Spacetime is truly *spatiotemporal*, rather than (separately) spatial and temporal. There are two ways, in particular, in which this unification is manifest. First, objects and events are separated by an invariant spatiotemporal interval (ds^2), and the extent of this interval is agreed upon by all observers irrespective of their state of motion. Second, observers in relative motion will resolve the invariant interval between any two events into *different* spatial and temporal components. In particular, observers in relative motion to an object will measure temporal intervals as dilated and spatial intervals (or length) as contracted.[87] Nonetheless, within both classical and relativistic spacetimes what it means for reality to be four-dimensional is given in similar terms, specifically in relation to measurement and the consequent assignment of spatial and temporal intervals.

As such, there is nothing in the meaning of 'existing four-dimensionally' that is incompatible with presentism. Yet it remains the case that it is considered incompatible and this seems to be for two reasons, both of which have been discredited by the arguments given previously.

First, the disparity between measured temporal intervals, in particular, counts against seeing the present (time) as ontologically privileged and this is connected with the denial of absolute simultaneity in the spacetime of the STR. Reasons for the presentist to abandon the commitment to absolute simultaneity have been given in § 3.6.1. If the presentist does not explicate the present in terms of a unique time, then there is no *a priori* reason why a presentist model cannot be compatible with an intrinsically four-dimensional reality. This does, however, require an alternative account of the present; this will be presented in § 5.8 and a supporting ontology is developed in Chapter 6.

Second, the intrinsically four-dimensional nature of reality gives rise to relativistic kinematic effects and these effects are used to support the conclusion of eternalism. However, this argument is based upon a premise (the absolute coincidence of measurement coordinates with spacetime points) that is shown to be false in the example of the Disintegrating Rod. This cannot, therefore, be used to argue for an incompatibility between presentist commitments and the notion that reality is intrinsically four-dimensional. The equation of existing four-dimensionally with four-dimensionalism, and ontological parity, is just not supported.

[87] Length is only contracted in the direction of motion.

For the presentist only that which is present exists. If absolute simultaneity and the notion of the present as a unique *time* is abandoned, as suggested, there is scope to regard the present as spatiotemporally structured, in a manner described by Minkowski spacetime. The idea to be pursued in the following chapters is that the present (as that which exists) is objectively and intrinsically dynamic, and it is this feature of reality that gives rise to its (four-dimensional) spatiotemporal structure. By *internalising* the dynamic aspects of reality in this way the problems (discussed in Chapter 1) associated with modelling objective passage in 3+1D terms (as *temporal* passage) are avoided.

If presentism *is* consistent with four-dimensionality, then it should be possible to provide an account of relativistic kinematic effects compatible with presentism; this is the subject of the following section.

3.6.3 An Explanation of Relativistic Kinematic Effects

I argue that relativistic kinematic effects (length contraction and time dilation) arise solely from the nature of measurement and the invariance of the speed of light. As such, these effects are compatible with a presentist position that regards 4D spacetime as the structure of an objectively dynamic reality.

Within Minkowski spacetime the invariant spacetime interval (ds^2) between events is an objective feature of reality; this is agreed upon by all observers irrespective of their state of motion. What is disagreed upon is how this invariant interval is resolved into separate spatial and temporal intervals.

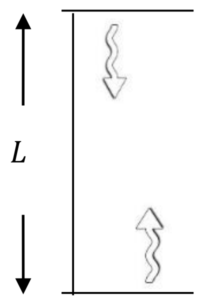
The significant point, emphasised previously, is that resolving this interval into separate spatial and temporal components *only* assumes meaning in the context of a measurement. Consequently, the separate (spatial and temporal) intervals themselves are not an objective feature of reality. Contrary to our intuitive notion of measurement, as involving the measurement of something that corresponds directly with some objective feature of reality, the measurement of spatial and temporal intervals under STR is merely the resolving of the invariant (and so objective) spatiotemporal interval into separate (frame-dependent) spatial and temporal intervals. To this extent, the description 'the measurement of spatial and temporal intervals' is misleading, they are not so much being *measured* as being assigned.

The discrepancy between the relative apportionment of spatial and temporal intervals encountered by observers in relative motion is referred to as time dilation and length contraction. This discrepancy arises for two reasons only:

1. Any measurement (viz. the assignment of separate spatial and temporal coordinates) requires the return propagation of a light signal.
2. The speed of light is invariant for all observers, regardless of their state of motion

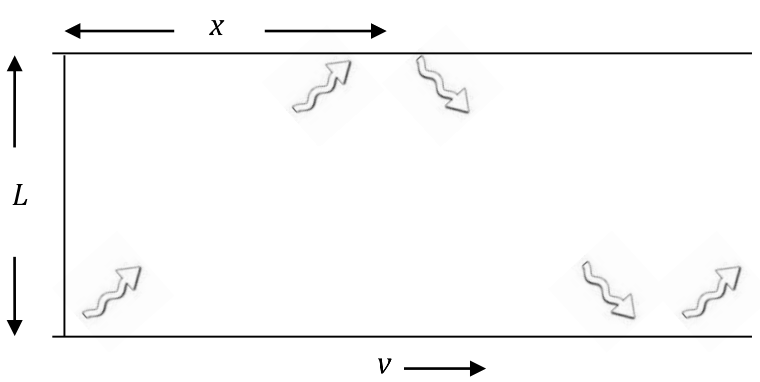
I illustrate how the discrepancy arises, in what follows, using the example of time dilation.

Any measurement of time intervals between events requires a physical clock. Consider a clock at rest with respect to an observer. The time interval, t_0, for one tick of the clock, is given by the distance travelled by a light pulse from one mirror to the other, divided by the velocity of light, c:



where $t_0 = L / c$

If the same clock is in relative motion, v, with respect to an observer it will be viewed by that observer as follows:



In this case, the time interval for one tick of the clock is also given by the distance travelled by the light pulse divided by c, but the (relative) distance travelled is different, and so the time interval is also altered and is given as follows:

$$t = \frac{\sqrt{L^2+x^2}}{c} = \frac{\sqrt{L^2+(vt)^2}}{c}$$

Solving this equation for t provides the relation between the two time intervals, t and t_0, allocated by the different observers:

$$t = \frac{L}{c} \cdot \frac{1}{\sqrt{1-v^2/c^2}} = t_0 \cdot \frac{1}{\sqrt{1-v^2/c^2}}$$

Thus the time interval for one tick on the clock (t) is longer (and so the clock is slowed) for the observer in relative motion as compared with the interval (t_0) for the observer at rest with respect to the clock. With respect to the observer in relative motion the light signal must *travel further* in order to complete one tick, and since the speed of light is a constant c for all observers the time interval must increase.

This result is quite general and applies to all clocks (not just light clocks) since, if it were not general, it would constitute a mechanism for the detection of absolute motion, in contradiction to the principle of relativity. All clocks (whether light clocks, body clocks or atomic clocks) involve motion of one form or another and that motion cannot be employed to detect a state of absolute rest.

It has been emphasised that adopting this line of explanation requires the presentist to abandon a 3+1D model of reality and accept that there are no uniquely and objectively *temporal* intervals between events, only objective *spatiotemporal* intervals (ds^2). Nonetheless, it may be countered here that even if the presentist accepts this, surely the existence of an invariant spatiotemporal interval implies the existence of past events, contrary to presentism?

In rejecting eternalism as the best explanation of length contraction (§ 3.5.1) it was emphasised that what is measured is always *past* with respect to the observers making the measurement. The (different) measurements of length made by Alice and Bob when they meet (point M) are equally valid descriptions of the rod *as it previously existed* (along the interval given by $x_{R1}t_0$ - $x_{R2}t_0$ in its rest frame). Though their assignments of spatial intervals (lengths) for the rod may differ, their measurements at that point would indicate their agreement on the spatiotemporal interval (*ds^2*) separating them (at M) from the (previously existing) rod. Nonetheless, the existence of this interval does not imply the present existence of the past rod (which would be contrary to presentism) or indeed the existence of anything that is not present (at M). The existence of the interval (between M and the rod as it previously existed) is given by the light beams, existing at M (that have arrived from either end of the previously existing rod) and the relevant laws of nature (the finite speed of light and its invariance for all observers).

In conclusion, accounting for the effects of time dilation, or length contraction, within the STR does not require recourse to ontological parity (or eternalism), it just needs to be understood that the assignment of separate temporal and spatial intervals is something that only acquires meaning in relation to measurement, and measurement in turn involves the transmission and reception of light signals. In virtue of the invariance of the speed of light for all observers the invariant spatiotemporal interval is resolved into spatial and temporal components differently by different observers.

3.7 Evaluating the Metaphysical Lessons of STR

It is clear that there are metaphysical lessons to be gleaned from the assumption of the truth of the STR. It is less clear what exactly these lessons are and, given the limited applicability[88] of the STR, we need to be cautious in evaluating what these may be.

The most significant conclusion of the STR is the intrinsic entanglement of spatial and temporal intervals between events: consequently, reality is objectively four-dimensional. Norton (2000), although somewhat sceptical about the ontological 'morals' that may be drawn from the STR, nonetheless

[88] By 'limited applicability' I refer to the extent to which GTR and emerging theories of QG revise or delimit the applicability of STR.

concurs that its central lesson is that the relativity of simultaneity 'expresses a profound entanglement of space and time' (p.188) into one four-dimensional, spatiotemporal reality. The crucial question is how this result is to be interpreted. The standard metaphysical interpretation of this result is the conclusion of eternalism. The preceding arguments have aimed to show that eternalism, as ontological parity, is not a metaphysical conclusion that we are justified in drawing. An intrinsically four-dimensional reality is equally compatible with presentism.

In assessing the metaphysical import of the STR I suggest that the question that should be the focus of attention is *why* it is that reality is intrinsically four-dimensional, rather than 3+1D. The explanation of how relativistic effects arise gives some indication of the answer to this question. The invariant spatiotemporal interval separating events represents an objective feature of reality. What is relative, or observer-dependent, is the resolving of this interval into separate temporal and spatial components; these differ between observers depending on their relative motion. In turn, it was noted that what underpins this difference is the invariant speed of light. Reality is intrinsically four-dimensional (rather than 3+1D) because of the invariance of the speed of light, *c*, for all observers, irrespective of their state of motion. This is a profound fact and it is *this*, I would suggest, that demands a suitable metaphysical interpretation.

The preceding discussions of the STR involve reference to light principally in relation to signalling and measurement. This gives the appearance that the theory is primarily instrumentalist, anthropocentric and 'observer-relative', with little scope for substantive metaphysical interpretation. Nonetheless, the key role that light occupies within the theory is not something that should be overlooked, however, understanding its significance requires a brief detour.

All particles that constitute the universe are either 'fermions' or 'bosons'. Fermions (e.g., electrons, protons, neutrons) are the fundamental building blocks of matter. On the other hand, bosons (e.g., photons, gravitons, gluons) are particles that mediate interactions between matter (fermions) and are generally the quanta of force fields. As quanta they are discrete packets of energy that transmit force or causal influence. The universe thereby divides neatly into matter and the interactions (or forces) between matter. Light is therefore more than a convenient method of signalling between observers. Light is composed of photons[89] and so has significance in that it mediates interactions between matter and propagates causal influence. The fact that its speed is finite means that there is no instantaneous influence, rather there is an objective and invariant interval (the spatiotemporal interval, ds^2) between events so connected, and it is this that gives rise to the spatiotemporal structure of reality.

The invariance of the spatiotemporal interval between events arises directly from the invariance of the speed (or velocity) of light since it is light (or some other form of the propagation of energy or influence) that connects events. Since velocity is defined in general terms as $\Delta x/\Delta t$, velocity therefore describes a unit interval of *motion*. Thus, the invariance of the velocity of light, c, means that its *motion* is invariant for all observers. It follows that the invariant spatiotemporal interval that separates events is an interval, or unit, of *motion*, rather than an objective spatial or temporal interval. It is this motion (of light or other propagating influence) that determines the spatiotemporal structure of reality. It is for these reasons that light cones figure in the construction of Minkowski spacetime, and that the latter is often described as causally structured.

Given this, I believe that the ontological moral to be drawn from the invariance of the velocity of light is that it is motion, rather than spacetime that is metaphysically primitive; in particular, that spacetime (or, more accurately, spacetime structure) is derivative of the motion and interaction of mass-energy. This premise will be pursued in Chapter 6 where an ontology for a compatibilist theory of presentism is developed based on Belkind's (2012) derivation of the structure of Minkowski spacetime from units of primitive motion. This route allows the establishment of a presentist model that regards Minkowski spacetime as the structure of an objectively dynamic reality.

[89] Photons are the quanta of the electromagnetic force field.

3.8 Concluding Thoughts

The aims of this chapter have been to show that the ontological commitments of presentism are compatible with relativistic physics, and to undermine claims that eternalism provides the best metaphysical interpretation of the results of the STR.

I have argued that presentism is compatible with an intrinsically four-dimensional reality and that the presentist has good grounds to abandon the commitment to a 3+1D reality, which regards the present as a unique time. Under the STR, existing four-dimensionally means that observers in relative motion will agree on the invariant spatiotemporal interval (ds^2) separating events, but assign different spatial and temporal descriptions (as a consequence of measurement) to that objective interval. It is the spatiotemporal interval that has objective significance, rather than the separate spatial and temporal components (which are observer and measurement-relative). This is compatible with a presentist model that adopts a reductionist structuralist view of spacetime, under which reality (the now) is structured spatiotemporally.

An explanation of relativistic effects has been given that is not reliant upon the metaphysical commitments of eternalism. Relativistic kinematic effects are the assignment of different spatial and temporal intervals by observers in relative motion. As such they are a feature of reality that only acquires meaning in relation to measurement, and this, in turn, requires the transmission and reception of light signals. In virtue of the invariance of the velocity of light, the invariant spatiotemporal interval is resolved into spatial and temporal components differently by observers in relative motion. The lack of an objective, unique temporal interval between events is only problematic for a presentist committed to formulating objective passage in 3+1D terms.

The presentist, in seeking a compatibilist account, should therefore embrace the fact that reality is intrinsically four-dimensional, rather than fall into a trap of equating an objectively dynamic reality with one that possesses a unique 3+1D description. Consequently, the present (or 'now') is not a unique, or indeed *any*, time.

CHAPTER 4 – PRESENTISM vs ETERNALISM – THE SCEPTICAL DEBATE

4.1 Introduction

I conclude in Chapter 2 that the best route to achieving a compatibilist model of presentism is to regard spacetime as the structure of reality. Since an eternalist might also subscribe to such a position, this influences the terms of the debate between presentism and eternalism, both of which are standardly construed as (mutually exclusive) theories of time. A danger arises if the course taken leads to an account that has little to distinguish it, metaphysically, from that of the eternalist. Indeed, commentators have recently suggested that there is no metaphysical substance to the debate and this has, to some extent, been supported by proponents of a structuralist position (e.g. Dorato, 2006b).

The aim of this chapter is to review and undermine the sceptical argument that the debate between presentism and eternalism has no ontological substance. I argue that the sceptical challenge misconstrues the debate by conflating matters metaphysical and linguistic, in a way that conceals the ontological core of the debate. The terms of the debate trap the presentist in the 'presentist's dilemma' (Meyer, 2013). I argue that the ontological substance of the disagreement turns on the nature of what it is that makes the existential claims, on each side, true. I describe how 'Existence Presentism' (Tallant, 2014) successfully circumvents the presentist's dilemma; understanding how this is achieved provides an important insight into how a compatibilist metaphysical foundation for presentism can be established. Achieving this is the ultimate goal of this thesis. Importantly, it also reveals that the debate between presentism and eternalism is not a debate about time, *per se*, but about the nature of concrete reality.

4.2 The Sceptical Argument

Eternalism and presentism are standardly considered to be theories of time. Nonetheless, both positions also represent ontologically substantial theses about what exists. A number of commentators have sought to argue that there is no substantial, ontological difference between the two positions. Rather, the debate collapses to a merely semantic one which turns on the temporal equivocation of ‘exists’, as it functions in the claims made on either side. This section reviews these claims.

Presentism regards the present as ontologically privileged. Though no unequivocal definition is accepted by all proponents, presentism can be formulated in general terms as the position that ‘only present things exist’[90] (Ingram and Tallant, 2018). Eternalism, by contrast, is the view that past, present and future things[91] exist and are ontologically on a par. Such an apparent divergence of opinion should, at first sight, translate into a clear existential claim that one side can accept and the other deny. However, this has proved to be far from the case.

A central claim is that the debate turns on the equivocation associated with the verbs ‘to be’ and ‘to exist’.[92] There is certainly a history of equivocation over the term ‘exists’. Austin (1962) reflects on the nature of existence to motivate the identification of some ‘contrast class’ in order to achieve a meaningful notion of existence or reality:

> a definite sense attaches to the assertion that something is real, a real such-and-such, only in the light of a specific way in which it might be, or might have been not real. This, of course, is why the attempt to find a characteristic common to all things that are or could be called ‘real’ is doomed to failure; the function of ‘real’ is not to contribute positively to the characterisation of anything, but to exclude possible ways of being not real [...] (p.70)
>
> ’Exist’, of course, is itself extremely tricky. The word is a verb, but it does not describe something that things do all the time, like breathing, only quieter – ticking over, as it were, in a metaphysical sort of way. It is only too easy to start wondering what, then, existing is. (p. 68)

[90] In order to distinguish presentism from the growing block view Ingram and Tallant proceed to qualify the position as ‘always, only present things exist’.
[91] Statements of both presentism and eternalism vary depending upon whether they range over things, objects, events or times. For example, Merricks (2006, p. 103) describes presentism as the view that ‘only the present time is real’.
[92] Such a claim is made, for example, by Pezet (2017), Savitt (2006), Dorato (2006b) and Lombard (2010).

Many commentators on the debate appeal to Rescher's (1966) analysis to facilitate a disambiguation of the notion of 'exists'. He highlights four ways of understanding 'is', as follows:

> (i) The "atemporal *is*" that means "is *timelessly*." ("Three *is* a prime number.")
>
> (ii) The "*is* of the present" that means "is *now*." ("The sun *is* setting.")
>
> (iii) The "omnitemporal *is*" that means "is *always*." ("Copper *is* a conductor of electricity.")
>
> (iv) The "transtemporal *is*" that means "is *in the present period*." ("The earth *is* a planet of the sun.")

Both Dorato (2006b) and Savitt (2006) exploit the equivocation in the notion of 'exists' to motivate a sceptical position. Savitt's argument employs Rescher's first two senses of 'is' together with a 'detensed' sense (is, was or will be), which he sees as exhausting the possible senses of 'is' with which to provide a meaningful distinction. Savitt argues that the eternalist cannot assert 'Isaac Newton **exists**' (in the tensed, 'is now', sense - Rescher's sense (ii)), whereas the presentist cannot deny 'Isaac Newton exists' (in the detensed sense). Further, both presentists and eternalists can agree that 'Isaac Newton **EXISTS**' (in the atemporal sense - Rescher's sense (i)) in so far as 'in 1666 one could say truly "Isaac Newton **exists"**' (in the tensed sense i.e. now). Thus, for all three characterisations of the verb 'exists' Savitt can find no formulation that satisfactorily distinguishes presentism from eternalism (2006, pp. 112-116).

Along similar lines Dorato (2006b) argues that *both* presentists (who do not wish to deny a commitment to the future existence of certain events) and eternalists are committed to tenseless existence, defined in the following manner:

> Def$_{2alt2}$: *e* tenselessly exists just in case *it was the case that e* exists (tensedly), or *e* exists (tensedly) or it will be the case that *e* exists (tensedly). (p. 102)

Existential claims, claims about what exists, employ 'exists' in the verb form. As such, any claim attributing existence to a singular object requires us to use the verb in either the tensed or tenseless form; once it is clear which form of the verb is being employed, the sceptical argument goes, it is not possible to arrive at the single thesis that one side is able to affirm and the other deny. As Meyer (2013, p.69) notes: 'It is a feature of English syntax that we cannot attribute existence to an object without committing ourselves, by our choice of tense for the verb 'to exist', to a past, present, or future time at which the object exists'. As a consequence, both presentists and eternalists agree that 'Aristotle exists (tenselessly)'. Conversely, both parties deny that Aristotle exists in the tensed sense of existence ('Aristotle exists *now*'). The argument concludes that once we specify the sense of existence that is intended there is no existential claim about which presentists and eternalists disagree. It appears that the difference between presentism and eternalism is merely semantic, rather than ontological. Influenced by Austin, Dorato urges that a genuine, ontic, distinction between eternalism and presentism requires 'a clear sense in which non-currently existing objects are unreal' (p.95).

4.3 The Presentist's Dilemma

The onus has generally been on the presentist to offer a definition of presentism that is sufficient to circumvent the sceptic's attack. Recent literature[93] has provided translations of the various statements proffered, in line with each possible sense of 'to exist', to render them either trivially true or obviously false. I illustrate this using the argument from Meyer (2013). Meyer argues that the triviality objection against presentism stands on the basis of 'a mix of logical analysis and empirical investigation […] Even if Einstein had been wrong and Newton right about the laws of mechanics, presentism would still have been either trivially true […] or obviously false' (p.85). He states the presentist thesis as:

(P) Nothing *exists* that is not present.

[93] For example, Dorato (2006b), Lombard (2010), Meyer (2013) and Savitt (2006).

Meyer argues that this formulation is unable to distinguish the 'present from other times' (p.67). He describes the impossibility of disambiguating the different meanings of 'exists', in order to establish a non-trivial and true claim, as the 'presentist's dilemma'. The presentist thesis, (P), is to be understood as either:

> (P1): Nothing *exists now* that is not present, *or*
>
> (P2): Nothing *exists temporally* that is not present (where 'exists temporally' means 'has existed, exists now or will exist').

(P1) is trivially true; this reading of 'exists' is too narrow since it already excludes any non-present objects. (P2) widens the scope of (P) and is thereby non-trivial, however (P2) is now rendered false by:

> (JC): Julius Caesar crossed the Rubicon

(P2) is rendered false since Julius Caesar has existed (and thus 'exists temporally'), yet he is not present. Thus, concludes Meyer, 'presentism is either trivially true or obviously false' (p.69). Tallant (2014) and Pezet (2017) similarly show how Rescher's analysis renders the presentist thesis, as standardly construed, either trivial or false, and both suggest alternative formulations, to be considered later.

In conclusion, several commentators have argued that the temporal equivocation of the verb 'exists', into either tensed or tenseless senses, renders the difference between presentist and eternalist existential claims merely semantic (rather than ontological). Further, attempts to formulate a statement of presentism that the presentist can uniquely assert, when translated into the alternative, temporal sense of 'exists', yields either a trivial truth or an obvious falsehood.

4.4 Responses to the Sceptic

In response to the sceptical claims, three main lines of argument are employed in an attempt to assert a meaningful difference between presentism and eternalism, and so escape the 'presentist's dilemma'. These are as follows: first, to describe the difference relative to some background spacetime theory, second, by analogy with modal actualism, and, third, by appealing to a notion of existence *simpliciter*. I discuss each in turn and highlight their shortcomings.

4.4.1 Reference to a Background Spacetime Theory

Savitt (2006, pp. 122-127) suggests that any constructive distinction between presentism and eternalism requires their description '*relative to some background spacetime theory'*. Given that both presentism and eternalism are claimed by their exponents to be theories about the nature of time, and the relationship between existence and time, formulating the debate in relation to spacetime theory should ostensibly provide a suitable arena for a substantial debate. Savitt's approach is to mirror Dummett's (1969, pp. 252-253) model of the realist/anti-realist distinction; he urges that we draw the distinction in terms of different perspectives on spacetime. Dummett describes the realist as conceptualising the whole of temporal reality by imagining themselves as standing (temporally) outside that reality and adopting a 'bird's-eye' perspective on the totality. The anti-realist, in contrast, does not consider it possible to conceptualise, or describe, the world other than from the standpoint of a given, temporal perspective.

For Savitt, the perspectives of Dummett's realist and anti-realist are analogous to the perspectives of the eternalist and presentist. These perspectives are though, for Savitt, compatible. Each is equally valid, as a perspective on reality, and each has its own explanatory advantages.

A similar consideration leads Dorato (2006b, p. 106) to describe the distinction between presentism and eternalism as merely 'pragmatic'. It relates to the usefulness in ordinary language of the two senses of existence: tensed, relating to the subjective, or internal perspective, and tenseless, describing the objective, external or scientific perspective on reality. Since both of these perspectives are equally compatible with Minkowski spacetime, the existence of Minkowski spacetime should not be employed to the advantage of eternalism, according to Dorato.

Though conciliatory in motivation, the idea that the distinction between presentism and eternalism is one of compatible, equally valid perspectives on spacetime is not advantageous to presentists, for the following reasons. First, both Savitt and Dorato commit the presentist to an assumption that spacetime can be uniquely foliated into hyperplanes of simultaneity, each of which occur successively. This is not acceptable to those who wish to establish a presentist account that is compatible with our best physical theories.[94] Second, such models imply that presentism offers a 'subjective view' on reality. The motivation for this, presumably, is that tensed *claims* about existence are subject-relative and their meaning can only be analysed in a token-reflexive manner. This, however, is merely a semantic or perspectival matter and is one example of how the metaphysical debate is easily confounded by the linguistic terms in which it is conveyed. In making what is an existential claim, the presentist does not proffer a subjective perspective on reality or spacetime. Their claim is a substantial metaphysical one.

Wüthrich (2012), though agreeing that the debate only acquires substance within the context of spacetime theories, rejects the compatibilist accounts of Savitt and Dorato. For Wüthrich, there is a substantive, ontological difference such that the two positions are not reducible to, or capable of being reconciled with, each other:

> eternalism can be understood as the position awarding existence to all events in $\mathcal{M}$, with the spatio-temporal properties given by the relations among the events as they are encoded in the metric field g_{ab} defined on $\mathcal{M}$. Presentism, on the other hand, takes an equivalence relation S which foliates $\mathcal{M}$ ("simultaneity") and then restricts physical existence to those events in the folium corresponding to "now". (p.5)

This approach, as with that of Dorato and Savitt, commits the presentist to absolute simultaneity and the objective reality of privileged, three-dimensional

[94] Chapter 3 describes how STR, in asserting the intrinsic four-dimensionality of reality, prescribes that there can be no uniquely *temporal* intervals between events. This restriction is magnified in the move to GTR (as discussed in Chapter 2) where the commitment to background-independence means that there is no physically meaningful, preferred foliation of spacetime.

hyperplanes of simultaneity which successively come into, and go out of, existence. It is this unique, universal time that stands as the privileged present, or 'now'. Wüthrich, himself, recognises that this route is not open to a presentist wishing to align their position with relativistic physics.[95] Nonetheless, many presentists and non-presentists alike[96] consider that A-theorists in general are, or should be, committed to an approach that posits privileged planes of simultaneity. Though this approach may render the debate substantive, as argued in the previous chapters, there are good reasons for the presentist to reject a formulation that equates the present with a privileged slice of spacetime.

There are additional reasons to avoid this line of argument. Tallant (2019, §4), in reviewing a formulation of presentism by Correia and Rosenkranz (2015), objects to their model on the grounds that it portrays reality as consisting of a single, static slice of spacetime. This type of objection originates with Merricks (2007), and Mulder (2016, p. 32) adopts a similar stance: he refers to 'negative presentism' as the view that takes the eternalist's time-line and removes everything apart from the present time (or moment), shrinking reality to a single, thin slice. This view is unacceptable to most 'standard' presentists on the grounds that it aligns too closely with eternalism and models the presentist's reality as merely a 'super-thin slice' of the eternalist's block universe. Such accounts provide nothing with which to explicate the ontological privilege of the present, or provide for the objective significance of tense. In conclusion, framing the debate with respect to a background spacetime theory does not appear to offer the compatibilist presentist with what is needed.

[95] It should be noted that Wüthrich himself espouses 'Ersatz presentism', a position which restricts physical existence to the present but permits abstract existents to be located at times other than the present.
[96] For example, Craig (2008), Hawley (2006), Saunders (2002), Zimmerman (2011), Nasmith (2011), Monton (2006).

4.4.2 The Analogy with Modal Actualism

An alternative approach to articulating the ontologically substantial difference between presentism and eternalism is by analogy with actualism. One of the early attempts is that of Adams (1986), following Prior (1960):

> As the actualist holds that there are no merely possible things, but only things that actually exist, so the presentist holds that there are no merely past or future things, but only things that exist now. For presentism, 'exists' in its sole primitive sense is a one-place predicate equivalent to 'actually exists now', and the presentist's primitive quantifiers range only over things that actually exist now. (Adams, 1986, p. 321)

Actualists can accept the truth of 'it is possible that unicorns exist' without committing to the truth of 'there are unicorns'; this is because the existential quantifier is inside the scope of the possibility operator:

(1) $\Diamond(\exists x)(Ux)$

Using this kind of approach, Sider (2006) and Crisp (2004) both utilise an analogous mechanism to assert the difference between the presentist and eternalist. Both parties in the debate can agree on tensed claims, such as 'Dinosaurs once existed', but they disagree on what makes such claims true and thus disagree over *what* exists. According to Sider (p. 78) the presentist's claim that 'dinosaurs once existed' is formalised as:

(2P) $\mathbf{P}\exists xDx$ (It was the case that: there exist dinosaurs)

Whereas for the eternalist the same claim is provided by:

(2E) $\exists x(Dx \wedge Bxu)$ (There exist dinosaurs, located temporally before us)

The difference, according to Sider, is that (2E) entails '$\exists x(Dx)$' but (2P) does not. For the presentist (2E) is false because '$\exists x(Dx)$' is false. Both presentists and eternalists *mean* the same thing in applying the existential quantifier, but, by analogy with modal actualism, since the existential quantifier is within the scope of the past tense operator, '**P**', the presentist is not committed to the existential claim of the eternalist, '∃x(Dx)'.

Sider anticipates the sceptical retort that this difference is superficial and merely a matter of syntax, rather than semantics. For Sider, the sceptic needs to demonstrate that the presentist's '**P**∃x' (or '*WAS* ∃x') does indeed count as a genuine quantifier (and so expresses the notion of existence) and thereby entails ∃x(Dx), in order to provide a successful counter-argument (*Ibid.,* pp. 80-82).

Crisp (2004) argues in a similar vein to Sider, but does so in order to draw a distinction between *de dicto* and *de re* intensional statements. In doing so he seeks to provide a sense in which the disagreement concerns a genuine dispute over *what* exists, rather than the sense (or tense) of 'exists'.[97] Crisp notes that presentists can accept the truth of *de dicto* statements (a statement that concerns propositions, rather than things), such as the following:

(RE_1): *WAS* (for some *x*, *x* is the Roman Empire and *x* will not exist in t_∞)

where 't_∞' represents the present moment (2004, p. 18).

Such statements contain the quantifier within the scope of the past tense operator. However, presentists would deny the truth of the corresponding *de re* statement (a statement that concerns the existence of things):

(RE_2): For some x, x was the Roman Empire and x is no longer present (*Ibid.*)

In the latter, the occurrence of the existential quantifier outside the scope of the past tense operator *does* imply an existential commitment. So, for Crisp, the triviality objection to the presentist thesis confounds a *de dicto* truth with a *de re* falsehood. The proposition 'Caesar crossed the Rubicon' is true *de dicto*, on the grounds that it means that there *was* someone, Caesar, who crossed the

[97] This contrasts with Lombard's (2010) criticism of the analogy with modal actualism. Lombard disputes that the analogy provides a genuine disagreement between the parties over '*what* exists'; whereas this *is* the case in the dispute between modal realists and actualists. He counters that the disagreement is simply about over which tense of 'exists' is being employed.

Rubicon. The presentist thus accepts statements of the form '**P**$\exists xRx$' but can still deny the *de re* claim (of the form '$\exists x$**P**Rx') that there currently exists some object, Caesar, that satisfies '**P**Rx'. The *de re* claim then, according to Crisp, is an assertion that the presentist can, unlike the eternalist, deny.

Tallant (2014, pp. 480, 489), however, maintains that the analogy with actualism does nothing to relieve the presentist's dilemma, and this has to do with the formulation of presentism that both Crisp and Sider provide. In the case of Crisp's argument, Tallant formalises his *de re* claim (that the presentist, unlike the eternalist, can deny) as follows:

(RE_2*): $\exists$x (x was the Roman Empire and $\neg$PRES x)

Following Meyer's (2005) distinction (§ 4.3) RE_2* may be translated in two ways: either in the tensed sense of existing *now* '($\exists_n$)', or, the tenseless sense '($\exists_t$)' of *temporally existing* (i.e., 'has existed, exists, or will exist'). In the tensed case ($\exists_n$), according to Tallant, RE_2* yields a contradiction (i.e., 'there now exists something that is not present'), whereas the alternative, tenseless reading ($\exists_t$) does not provide something that the presentist can 'sensibly deny'.

Tallant presents a similar analysis of Sider's (2006) argument; again, considering both senses of 'exists' employed in the application of '$\exists$' in **WAS** $\exists$x(Dx) and $\exists$x(Dx). If, along the lines of Sider's counter-challenge to the sceptic, the presentist position is stated using the tensed reading of the quantifier ($\exists_n$):

$\neg$ [**WAS** $\exists_n$x(Dx) entails $\exists_n$x(Dx)]

This leads to a claim upon which both presentists and eternalists can agree, since what is within the square brackets is clearly false. Alternatively, under the tenseless sense of the quantifier, ($\exists_t$), the presentist position translates as:

$\neg$ [**WAS** $\exists_t$x(Dx) entails that $\exists_t$x(Dx)]

However, this is false since **WAS** $\exists_t$x(Dx) *does* entail $\exists_t$x(Dx) and so cannot be used by the presentist to distinguish their position after all.

The analogy with actualism thus appears to fail. The notion that an ontological difference can be achieved solely by preferential placement of the existential quantifier, ∃, fails since the presentist is once again restricted to the choice between either tensed or tenseless senses of ∃, and thereby forced, once again, into the presentist's dilemma.

4.4.3 The Appeal to Existence *Simpliciter*

In drawing the analogy with actualism, the quotation above from Adams (1986) appeals to the sense in which 'exists' is employed by the presentist 'in its sole primitive sense' and this leads to the thought that an appeal to a primitive notion of existence, or existence *simpliciter*, could offer an alternative mechanism by which the presentist might avoid Meyer's 'presentist dilemma'. The thought is that existence is something to be comprehended, in an 'untensed' sense, beyond its tensed or tenseless senses, and this is proposed by Hestevold and Carter (2002). They draw upon an analogy with Lewis' modal realism in an attempt to detach existence from existence at a particular time, and describe it thus:

> *X* exists *simpliciter,* if and only if, *X* is among the things that the universe includes—if and only if *X* is *real*. That *X* exists *simpliciter* does *not* alone imply that *X did* exist, that *X* presently exists, nor that *X will* exist. (2002, p. 499)

As such they consider this permits a 'non-trivial' statement of the presentist thesis, as follows:

> P_6 Necessarily, if *x* exists$_s$ [*simpliciter*], then *x* presently exists (*Ibid.*, p. 499)

However, Lombard (2010) maintains that Hestevold and Carter's notion of 'existence *simpliciter*' is not obviously different from his own notion of 'is real':

> If some object is real, then it either existed, exists, or will exist (or would exist even if there were not times). Thus, to say of some object that it is (now) real is to say neither that it did nor that it will exist [...]. Thus

> Hestevold and Carter's (2002a) concept of tenseless existence seems clearly to match my notion of what is real. (p. 74, footnote 23.)

As a consequence, Lombard argues, P_6 either implies that Aristotle exists now or that Aristotle is not real, both of which are false. Further, if P_6 is considered true at all times, the implication that follows is that all things that exist *simpliciter* exist at all times. This is clearly contrary to presentism unless 'presently' refers to a unique time in which case, Lombard challenges, the presentist has to say which time it is and why it is so special.

Meyer (2013, p. 70) also considers it is difficult for the presentist to capture the required sense of existence *simpliciter*, one that is able to transcend the temporal in a manner that works. In evaluating its potential he translates the standard presentist thesis as follows:

> (P3): Nothing *exists simpliciter* that is not present

Meyer contends that if a given object exists *simpliciter* there seem to be limited candidates for the way in which it might exist. If the object exists as an actual, concrete entity ('in time') then it must have existed at *some* time, in which case his tenseless notion of existence (P2, § 4.3) applies, in other words, it 'has existed, does exist or will exist'. The only other possibilities, which provide some sense of existing 'outside time', are existence as an abstract entity or existence as a possible entity. However, construing a presentist thesis in terms of either possible or abstract existence fails to align with the presentist position. Meyer concludes that the presentist's dilemma remains.

The problem with the notion of existence *simpliciter* is that it is difficult to elucidate. The difficulty arises because existence *simpliciter* needs to be a sense of existence that is 'untensed' or 'detensed', a sense that is beyond the tensed or tenseless senses of existence that make any statement of the presentist thesis susceptible to the presentist's dilemma. Yet, it is clear that the presentist's claims about existence are about *concrete, spatiotemporal* existence, existence which is in, or of, time. The motivation behind existence *simpliciter* is to detach existence from existence at a particular time, yet concrete existence is inextricably tied to existence at a particular time.

This section has reviewed three ways in which presentists have attempted to formulate their position in an ontologically substantive manner, in response to the sceptical claim. Formulating the debate with reference to a background spacetime theory, although providing a substantial difference between the two sides, compromises the presentist position. It renders it incompatible with physical theory and models presentism as a 'limiting case' of eternalism. On the other hand, the analogy with modal actualism and the appeal to existence *simpliciter,* both fail to avoid the 'presentist's dilemma': presentism is rendered either trivially true or false. In the next section I revisit the sceptical claim and argue that it is based upon a conflation of metaphysics and linguistics.

4.5 The Sceptical Claim Examined - A Conflation of Metaphysics and Linguistics?

In assessing the sceptic's claim it is first useful to consider the area of agreement on both sides of the debate. For both presentists and eternalists the subject of their respective claims is concrete, spatiotemporal existence and entities that exist spatiotemporally. References to possible and abstract existents, and existence 'beyond' time, serve merely to muddy the waters of the debate. The equivocality, or otherwise, of the concept of existence, upon which the sceptical argument is based (§ 4.2), is therefore irrelevant to establishing the substance of the disagreement between presentism and eternalism. There is no equivocality over the category of existence referred to on each side of the debate, since the claims of both parties refer to concrete existence.

It is precisely for this reason that both parties in the debate *can* agree on the truth value of both tensed and tenseless existential claims. As noted earlier, in making existential claims about particulars we are linguistically restricted to using 'exists' in the verb form, which means that such claims can be interpreted in either a tensed or tenseless sense. Since all concrete entities exist at *some* time or other and, if there is no dispute at which (B-series) time a given entity exists, then there need be no dispute over the truth value of the relevant existential claim (tensed or tenseless) since the truth values for those claims are provided by the relevant B-series temporal indices.

For a *tensed* existence claim (e.g. 'Clinton exists now') the truth value of the claim is given with reference to token-reflexive truth conditions which make reference to a B-series time:

> 'Clinton exists *now*' is true iff a token utterance or inscription of it is simultaneous with the existence of Clinton

Presentists and eternalists can similarly agree on the truth value of *tenseless* existence claims:

> For all *x*, such that *x* is concrete, *x* does, did or will exist is true iff *x* exists at some (B-series) time

This is because the right-hand-side of the embedded biconditional is simply a restatement of the condition that *x* is a concrete entity.

The sceptical claim succeeds *only* to the extent that once the tense of the relevant claim is settled then there is no disagreement. Further this is, as the sceptics themselves note, merely a semantic matter and should not be seen as the true source of the disagreement. This fact is simply a vagary of linguistic reference and should not detract from locating the ontological substance of the debate. In order to ensure that the respective positions locate the metaphysical core of the debate we need to ensure that the debate does *not* turn on the meaning (or truth value) of existence *claims*. If, indeed, there *is* a substantive disagreement, the ontological substance of that disagreement will turn on the *nature of what it is that makes* the relevant claims true.[98] The sceptical challenge has not ruled out the possibility of locating this ontological substance and to this extent the metaphysical debate needs to be kept on track.

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[98] Stoneham (2009) argues in a similar vein in asserting that a substantive difference between presentism and eternalism may only be achieved given acceptance of the Truthmaker Principle (If *p* is true then there exists some object, *x*, such that the existence of *x* strictly implies the truth of *p*).

4.6 An Intuitive Sense of the Ontological Difference

Despite the force of the sceptical claim and the difficulties in rendering presentism in the form of a substantial thesis, there is a sense in which there is a ontologically significant difference between the two sides in the debate; as Zimmerman (1998, p. 209) notes, 'presentism is neither a boring truth nor an interesting falsehood'.

From the viewpoint of the presentist, the substance of the debate lies with the assertion that the present moment is ontologically privileged. The eternalist denies that any moment is ontologically privileged; their set of existent entities is larger. Therefore, the presentist thesis is more ontologically restrictive.

We can certainly gain an intuitive grasp of the sense of this metaphysically significant difference. This is illustrated by Peterson & Silberstein's (2010, p. 221) reference to 'Newton's God's' view of the universe. Irrespective of the question of determinism, were Newton's God a presentist, observing the universe from a fifth-dimensional 'perch' outside (four-dimensional) spacetime, they would see only a continually evolving present. If Newton's God were an eternalist, in contrast, they would 'observe' all concrete events, past, present and future. To this extent there is a debate about *what* exists.[99] Crudely, the eternalist has 'more stuff' in their set of existent entities than the presentist. I would suggest that both eternalists and presentists *do* have such an intuitive grasp of the metaphysically significant difference between them.

This reflects Wüthrich's (2012) view that it is possible for the presentist and eternalist to establish a substantive difference simply by enumerating what physically exists. As Wüthrich emphasises, the debate 'concerns *physical existence* rather than our language used to express existence claims' (2012, p.4) and so the debate should not be thrown off course by the latter. Consequently,

[99] Contrast Lombard (2010, p. 72), who states that: 'The alleged controversy between presentists and eternalists does not involve, as the other metaphysical disputes mentioned by Sider do, any dispute about what exists. There may be genuine issues over which presentists and eternalists disagree; but those issues are not about the reality of time, the reality of what exists in time, or the nature of persistence'.

there should be a way of linguistically representing this without thereby forcing an ontological commitment.

In conclusion, the 'presentist's dilemma' is an artifice of the terms under which the debate has standardly been formulated. The presentist should therefore avoid falling into the trap of formulating their position in terms of claims about what exists. Despite the fact that presentists and eternalists can enumerate what exists and what does not exist, and thereby end up with different sets of existent entities, any attempts to formulate a *claim* about the existence of *given* concrete particulars is subject to either a tensed or tenseless translation and thereby produces a statement upon which both can agree. Getting to the ontological heart of the debate requires representation without ontological commitment, yet this seems impossible to achieve within the arena of existential quantification.

4.7 The Ontological Heart of the Debate

I have argued above that the ontological substance of the debate turns on the *nature of what it is that makes* the respective existential claims true (§ 4.5). The fact that both sides target concrete existence, in making their claims, does not imply that they agree on the nature of the truthmakers grounding those claims.

For the eternalist what makes a given existential claim, *X* exists, true is its given (B-series) spatiotemporal location; this determines, and is sufficient for, the existence (or reality) of *X*. Since all concrete particulars are spatiotemporally locatable, all concrete particulars exist.

This stance on the nature of concrete existence is highlighted in the contributions of Dorato (2006b) and Savitt (2006). For Dorato the *existence* of any concrete event *just is* its occurrence (or location) at a given spatiotemporal point:

> [...] in Minkowski spacetime timelike-separated events are objectively, invariantly timelike-related, and events, *by definition, occur or happen*. They do so, so to speak, *a priori*. […] the fact that in a block-view pairs of

> timelike-separated events *exist at their location* […] And the events' very being is their occurring. (Dorato, 2006b, p. 97)

In a similar vein, Savitt (2006, p. 123), in characterising the difference between eternalism and presentism with reference to a background spacetime theory (such as Galilean spacetime **G**), explicitly states the eternalist position as:

> CE5 An event *e* **Exists** iff $e \in$ **G** (where **Exists** means 'was, is or will be')

An event exists iff it can be associated with a given point on the spacetime manifold, **G:** 'the existence of an event for an eternalist is simply its being in **G**' (p.126).

For the eternalist therefore, concrete existence just is existence *at a particular (B-series) time, t*, or at a particular *location in* spacetime. Spatiotemporal location is a sufficient determinant of concrete existence. The eternalist thesis might therefore be formulated as follows:

> E_T: Concrete existence is occurrence at a particular spatiotemporal location (or, spacetime point)[100]

This is not the case for the presentist who, although accepting that B-series temporal relations can hold between concrete entities, does not accept that they determine an entity's existence.[101] For the presentist, what makes '*X* exists' true is that *X* exists *now*. The arguments of the previous chapters have emphasised that the present should not be seen as a unique, or indeed any, B-series time. If the 'now' is not a B-series time then, for the presentist, spatiotemporal location does not determine the existence of concrete particulars. Consequently, the presentist must regard existence as metaphysically prior to B-series time (or spacetime). It is for this reason that the arguments of the preceding chapters suggest that the route to a successful account of presentism (one that is both

[100] It is accepted that this restricts the discussion to our universe, as a four-dimensional spatiotemporal universe. As Baron & Miller (2013) indicate, timeless eternalist universes are also a possibility.

[101] The reader is referred back to § 3.6.3 where it is argued that the presentist is able to account for the fact of an invariant spatiotemporal interval between events without compromising their ontological position. The way in which the presentist might model Minkowski spacetime as the structure of an objectively dynamic reality is presented in Chapter 6.

compatible with physical theory and avoids the standard problems associated with dynamic theories of time) is one that regards B-series spacetime as the structure of an objectively dynamic reality. Such an approach reflects the motivation behind the appeal to existence *simpliciter*: a sense of existence that is *prior to* spacetime.

In conclusion both presentists and eternalists make a different, but metaphysically substantial, claim about the nature of concrete existence. The challenges that face a successful formulation of presentism are therefore twofold. First, the presentist must avoid formulating their position in the form of an existential *claim*, since this falls foul of the 'presentist's dilemma'. Second, presentism requires a mechanism to formulate both existence, and the ontological privilege of the present, as metaphysically prior to (B-series) time without generating the conclusion that existence is somehow timeless or atemporal. The problems discussed above have prompted recent contributors (e.g. Merricks, 2007, Tallant, 2014, Mulder, 2016 and Pezet, 2017) to attempt to reformulate the presentist thesis on a more fundamental level, away from seeing the present in terms of a present 'time', and instead formulating it in purely ontological terms. These models are reviewed in the following section.

4.8 Existence Presentism

The foundations of Existence Presentism can be seen in the work of A.N. Prior (1970) and later Craig (1997);[102] however, Merricks (2007) (and previously Zimmerman, 1996) represents one of the first moves towards an identification of existence with presence, more recently proposed by Tallant (2014). Merricks notes the common misconstrual of presentism on the basis of the eternalist's view of existence as existence at a particular time. He suggests, on behalf of the presentist, that 'while objects exist at the present time, they exist at no other times, since there are no other times at which to be located' (p.124). He argues that the objectors:

[102] Craig (1997) describes Prior (1970) as suggesting an equation between the concepts of the present and the real: 'the present simply *is* the real considered in relation to two particular species of unreality, namely the past and the future' (p. 245).

> (wrongly) ascribe to presentists the eternalist's claim that to *exist at a time* is to be located at some super-thin slice of being. But presentists should no more accept this than the non-Lewisian should accept that to possibly exist is to be located in some universe. (p.124)

Merricks' point is that there is no such entity as 'the present time'. Rather, he suggests that presentists 'should, instead, say that *existing at the present time* just is *existing*' (p.125). Obviously Merricks, here, still refers to the present in terms of a 'present time', despite his rejection of the notion of there being an entity which stands as the 'present time'. This is abandoned in Tallant's formulation of Existence Presentism.

Tallant, in acknowledging Merricks, notes that this approach:

> ties presentism to a claim about the nature of existence. It seems right that presentism ought to be understood, not merely as a thesis concerning the *number* of times that exist, but also as a thesis with a commitment to the *nature* of those times (p.493).

Nonetheless, there are problems with Merricks' rendition. Tallant exposes this by disambiguating it along the lines of Meyer's (2013) treatment of the (standard) presentist thesis. Employing Meyer's two senses of 'is' (§ 4.3) reveals that Merricks' formula still succumbs to the presentist's dilemma, in yielding either a trivially true or an obviously false proposition:

> (M1): Existing at the present time just is *now* existing
>
> (M2): Existing at the present time just *has been, is, and will be,* existing
>
> (Tallant 2014, p. 393)

Tallant notes that these arguments also extend to Zimmerman's (1996) formulation:

> to be present *just is* to be real or to exist (p. 117)

Tallant concludes that the only way to avoid these inexorable problems is to make an *identity* between presence and existence.

EP: Presence is existence (p.494)

Although the ‘is’ is the ‘is’ of identity, the copula is also tensed (presence ‘is *now* identical with’ existence) and this yields a statement to which the eternalist cannot also subscribe. He illustrates this with the example of the Battle of Hastings: ‘The Battle of Hastings is not present and so the eternalist cannot endorse EP’ (p.494). Objects qualify as present by existing and this is something that no eternalist would accept. It is relevant, here, to note the difference between Tallant’s formulation and that of Zimmerman which, though close, Tallant also argues is trivially true. Zimmerman uses ‘exists’ in the verb form and, as such, is subject to translation along tensed lines to yield a trivial truth, as follows:

D1) To be present just is to exist-now (Tallant, 2014, p. 493)

The difference, then, is that under Tallant’s formulation ‘existence’ shifts from its verb form to its noun form. Consequently, it is not *existence* that is tensed rather it is the ‘is’ of identity. As such ‘existence’ is freed from any connotations relating to time or tense; this succeeds in providing the more primitive sense of existence, along the lines sought by the appeal to ‘existence *simpliciter*’. Further, from the identity, presence is also freed from any equation with a unique (or indeed any) *time*, and this provides a route for establishing existence as metaphysically prior to (B-series) time.

Mulder (2016) concurs that Tallant’s Existence Presentism does not succumb to Meyer’s disambiguation arguments and that it represents a shift ‘from existence claims proper to a claim *about* existence’ under which ‘existence becomes an inherently temporal notion, and therefore no longer requires being linked to times’ (p.34). It also abandons the notion of times as ‘locations’. The debate between the presentist and eternalist is thereby established as an ontologically significant debate about the *nature* of existence; since the equation of presence and existence is something that would be denied by the eternalist.

4.9 Conclusion

The arguments of Chapter 2 suggested that a compatibilist account of presentism should adopt a structuralist account of (B-series) time, one that sees time as the structure of reality. Since such an account of time is equally available to the eternalist, this chapter has been concerned with undermining the sceptical claim that there is no ontologically substantial difference between presentism and eternalism. It is argued that, of all recent formulations of presentism, it is only Existence Presentism that successfully asserts this difference and rebuts the sceptic. In asserting an identity between existence and presence, Existence Presentism is able to circumvent Meyer's 'presentist's dilemma' since the formulation of Existence Presentism is not a claim that can be countenanced by the eternalist.

The most significant implication of Existence Presentism, from the standpoint of this thesis, is that it frees presentism from any metaphysical dependency on B-series time. This has two consequences. First, it opens the door to a compatibilist account of presentism, since there is no need for the present to be identified with a unique, or privileged, B-series time. Second, since existence is no longer regarded as existence in time, or at a time, this offers the opportunity to develop an account under which B-series time is derivative of the structure of an objectively dynamic reality. This, though, leaves open several questions. In particular, the question of how an objectively dynamic reality might be modelled independently from (B-series) time. It also leaves open the question of the nature and role of tense (which, for the presentist, indicates something metaphysically fundamental about reality) and its connection with B-series time. These questions will be considered in Chapter 5, which proposes a suitable account of persistence and change within a model of Existence Presentism that aims for alignment with physical theory.

CHAPTER 5 – TAKING TENSE SERIOUSLY: A SUITABLE ACCOUNT OF PERSISTENCE AND CHANGE FOR EXISTENCE PRESENTISM

5.1 Introduction

The arguments in the preceding chapters motivate the position that a successful compatibilist account of presentism should be based upon the following key elements:

EP: an identification of the present with existence and a rejection of the idea of the present as a unique (B-series) time – 'Existence Presentism' (from Chapter 4);

RS: a reductionist account of B-series time which reduces time to the structure of an objectively dynamic reality – a 'reductionist structuralism' (from Chapter 2).

Both these commitments have implications for corresponding accounts of change and persistence. The task of this chapter is to formulate an account of each that best aligns with the compatibilist model of Existence Presentism under development.

A recurring theme underpins the arguments of this chapter, this is that the presentist requires some means of modelling an objectively dynamic reality independently of B-series time. I refer to this as *internalising* those aspects of reality within the present. It is only by doing so that the presentist can avoid the standard McTaggartian problems associated with temporal 'flow' (§§ 1.4.1 & 1.4.2) and side-step the 'presentist's dilemma' (§ 4.3). Adequate formulations of persistence and change will prove key to achieving this goal. These will also form the foundation of an appropriate ontology for presentism (in Chapter 6), one which utilises categories appropriate to an objectively tensed reality.

The arguments of this chapter will proceed along the following lines. After outlining the standard accounts of change and persistence (endurance and perdurance), I set out criteria for a suitable account of change and persistence, given the prior commitments of the Existence Presentist. I then argue, on the basis of these criteria, that neither of the standard accounts is suitable since each is underpinned by the B-series time of eternalism. Even strictly tensed approaches to endurance (e.g., Zimmerman, 1998 and Baron, 2018) encounter problems; in particular, they fall foul of Lowe's argument that transtemporal identity cannot be grounded without circularity. This, together with Tallant's (2018) arguments, suggests that the Existence Presentist should abandon the idea that persistence is provided by transtemporal identity. Consequently, I argue that suitable accounts of persistence and real change should be informed by how it is that reality is objectively tensed. I do this through an assessment of the objective correlates of tense, and this indicates the mechanism needed to internalise the dynamic aspects of reality. This, in turn, motivates a reformulation of persistence as continuing existence and a re-definition of change in terms of objective creation and annihilation.

In what follows, I refer to the Existence Presentist as a presentist who 'takes tense seriously',[103] or is a 'serious presentist'.[104] In using this description, I mean that the Existence Presentist subscribes to *both* of the following theses:

1. reality is objectively tensed, and
2. the present is not a B-series time.

Fine's (2005, p. 299) distinction between ontic and factive presentism is relevant here. Ontic presentism is an ontological thesis about *what* there is.[105] Factive presentism is a metaphysical thesis concerning *how* things are.[106] The Existence Presentist, as a 'serious' presentist, not only subscribes to the ontic claim (that only present things exist) but also asserts that tense reflects something ontologically fundamental about reality. As a result, 'serious' presentism, as well as asserting an ontologically restrictive thesis about *what*

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[103] Note that this usage of 'taking tense seriously' contrasts with that of Zimmerman (2005, p. 405), who understands it as 'an affirmation of the eliminability of *temporally perspectival propositions*'. Under the latter interpretation 'taking tense seriously' can be compatible with the commitments of the B-theorist.

[104] The description of a 'serious presentist' here contrasts with standard usage under which 'serious presentism' is described as the view that objects can possess properties or stand in relations only at times at which they exist (e.g., Inman, 2012).

[105] In particular, 'the view that only presently existing things are 'real' in some or another sense of the term' (Fine, 2005, p. 298)

[106] In particular, 'the view that reality is tensed' (*Ibid.*, p. 299)

there is, must also be a thesis about *how* things exist (in other words, that reality is objectively tensed). This position distinguishes the compatibilist, Existence Presentist from a presentist for whom the ontologically privileged present *can* be associated with a thin slice of spacetime, perhaps on the grounds of pursuing an alternative interpretation of STR.[107]

5.2 The Standard Models of Change & Persistence – Endurance and Perdurance

As described in Chapter 1, the standard accounts of persistence, endurance and perdurance, are geared towards providing a solution to the problem of temporary intrinsics. Both accounts aim to provide an understanding of how things can both stay the same over time (identity) and yet undergo real change (a change in intrinsic properties). The implied contradiction here arises from an inherent tension between the following two assumptions:

(i) Persistence is numerical identity over time and numerical identity is provided for by Leibniz's Law, namely: for all *x* and for all *y*, *x* and *y* are identical iff *x* and *y* are qualitatively indiscernible.

(ii) Change is the possession of incompatible intrinsic properties at different times.

Both endurance and perdurance use what I have referred to as 'temporal indexation' to circumvent the implied contradiction in any attribution of change to a persisting object. Further explanation of how temporal indexation works to ameliorate the problem of temporary intrinsics, under each model, is given in § 1.5.1.

Under endurance, persistence is given by numerical identity over time: an object is wholly present at each time at which it exists. 'Wholly present' is generally taken to mean devoid of temporal parts (Lowe, 1998) or existing in its 'entirety at one particular time, and '"no-when" else' and 'existing exclusively at

[107] For example, Craig (2008) provides a comprehensive argument in favour of a Lorentzian (3+1D) interpretation of STR on both empirical and metaphysical grounds. Brown (2005) similarly adopts an alternative interpretation which regards relativistic kinematic effects as being dynamical in nature.

a particular time' (Ingthorsson, 2009, p. 9). In order for entities to exist wholly and completely at each of the many times at which they exist, endurantism requires temporal movement, or passage. To avoid the problem of temporary intrinsics, statements about change require either the temporal indexation of the copula (e.g., A is-at-t_1 F) or of the relevant predicate (e.g., A is F-at-t_1).

Under perdurance, there is no genuine identity over time. Rather, persistence is viewed as a relation between distinct temporal parts existing at different times. Under this model it is the object that is temporally indexed by treating it as a sum of temporal parts (e.g., A-at-t_1 is F). This mechanism also avoids the contradiction arising from the problem of temporary intrinsics, since the incompatible properties are possessed by different entities (the different temporal parts).

Though endurance and perdurance, through temporal indexation, successfully circumvent the problem of temporary intrinsics, neither is suitable for a compatibilist account of presentism. Prior to providing the reasons for this I first set out criteria for a suitable account in the following section.

5.3 Preliminary Desiderata for a Suitable Account

Endurantism and perdurantism are underpinned by common assumptions about change and persistence (outlined in (i) and (ii) above) and this signposts the problems to be encountered by a presentist model. First, change and persistence are both characterised by reference to *different* times. Yet, for the presentist, there is only a single moment, the present. Second, the proposal (RS, §5.1) that (space)time be seen as the structure of an objectively dynamic reality means that time is not metaphysically primitive.[108] Such a position is in tension with the formulations of change and persistence under the standard accounts, where time bears the definitional burden. The separate commitments of presentism and compatibilism therefore motivate certain desiderata for a

[108] As described in Chapter 2, I use the term 'metaphysically primitive' as shorthand for 'metaphysically independent of the existence of entities'.

suitable account of both persistence and change which I describe in the following two sections.

5.3.1 Independence from B-Series Time

The first criterion is that *both* persistence and change are formulated independently of B-series time. The reason for this is as follows. Under presentism only present things exist; consequently, that which exists must both persist and change in the present.[109] Since, under the preferred formulation of presentism (Existence Presentism), the present is independent of any, and all, B-series times, change and persistence must be construed independently of B-series time. This criterion is also consistent with the commitment to a compatibilist approach that views time as the structure of reality. The problems associated with emerging theories of quantum gravity (Chapter 2) motivate abandoning the view that time is metaphysically primitive, yet this view is a central assumption of the standard accounts of endurance and perdurance (as argued in Chapter 1). If time is not metaphysically primitive, then both change and persistence need to be formulated independently of time. The first desideratum is therefore as follows:

> (D1): Change and persistence are formulated independently of B-series time.

5.3.2 'Real' Metaphysical Change versus Temporal Variation

The second criterion concerns change only. The Existence Presentist, as a 'serious presentist', understands change in a fundamentally different way from the eternalist, and this is connected with their differing ontological commitments. In particular, the Existence Presentist subscribes to 'real change' and this is different from mere temporal variation, as the following explains.

In Chapter 4 I argue that eternalism equates existence with occurrence at a particular spatiotemporal location and this aligns with a commitment to the ontological parity of past, present and future. This leads to an approach to

[109] Admittedly, this only follows for a presentist who accepts the objective reality of change and persistence.

change that defines it in terms of a background, B-series time. Change is thereby metaphysically dependent on time and, since all times are ontologically equivalent, this has the consequence that change and objective becoming are expressed by temporal variation. Change, as temporal variation, is the instantiation of different properties at different temporal locations in a manner analogous to qualitative variation at different spatial locations. This means that descriptions such as 'the poker is hot at time, t_1 and cold at time, t_2' do not express a qualitative variation that is *fundamentally* different from descriptions that state it is 'hot at one end' and 'cold at the other', at a given time (Sider, 2001, pp. 212-214). This is the 'static' view of change.

This is not how the 'serious' presentist views change. Both Pezet (2017) and Tallant (2019, p. 13), amongst others, adopt the position that mere temporal variation is insufficient to provide for real change. They hold the presentist to subscribe to a view that the *whole* of what exists is objectively and continually changing, and it is this feature of reality that is captured by tense. Real change is not dependent upon spatiotemporal location and it is not different amounts of what there is *at* different temporal locations. Pezet describes such real change as 'metaphysical change' (2017, p. 1824), to distinguish it from temporal variation; as such 'metaphysical change' is denied by the eternalist.

In order to guarantee a distinction, metaphysical change has to be described in a way that is not underpinned by a token reflexive account that references B-series temporal indices. To achieve this Pezet disambiguates two senses of the existential quantifier. The fundamental, unrestricted quantifier, ($\exists_{As}$), represents '*what there is as of now*', or the constitution of reality *when* it is now; this captures *all* of what there is. A more restricted quantifier, ($\exists_{At}$), which is derivative of $\exists_{As}$, expresses '*what there is at the now*', or what is temporally located at the now. Using these different senses of the quantifier allows an expression of change to be rendered into two forms, one of which is denied by the eternalist. Take, for example, the statement 'there are now humans, but in the future there will be no humans'. According to Pezet this can be formalised in the following two ways:

(1*) $\mathbf{N}\,(\exists_{At}x(Hx))\ \&\ \mathbf{F}\,(\neg\exists_{At}\,y\,(Hy))$

(1**) $\mathbf{N}\,(\exists_{As}x(Hx))\ \&\ \mathbf{F}\,(\neg\exists_{As}\,y\,(Hy))$

(1*) as an expression of change can be accepted by both eternalists and presentists, but describes merely '*temporal variation*'. This accounts for the sense in which both presentist and eternalists can agree with the statement 'It is now the case that there is at the now a human, and it will be the case that there is not at then a human' (*Ibid,* p.1824). On the other hand, (1**) describes '*metaphysical change'*, or real change, which is accepted by the presentist but denied by the eternalist. In the form (1**) the same expression of change ('there are now humans, but in the future there will be no humans') translates as 'It is now the case that there is as of now a human, and it will be the case that there is not as of then a human' (*Ibid*).

Regardless of whether the formal expression of this distinction works, or not,[110] the idea captures an intuitive distinction in the way in which change is viewed by the presentist and the eternalist. In particular, for Pezet 'metaphysical change presupposes that what there *is* or the way things *are*, is temporary, and that is just another way of saying that the italicised "is" and "are" are indeed tensed' (*Ibid,* p. 1825). The 'serious' presentist - the presentist who subscribes to the position that reality is objectively tensed - should therefore additionally subscribe to the thesis of metaphysical change:

(C_M): The whole of what exists is changing

To support this assertion, I provide an argument, in the following section, to show that the position that reality is objectively tensed implies metaphysical change.

The concept of metaphysical change distinguishes the account of the 'serious' presentist not only from that of the eternalist, but also from other A-theorists who subscribe to a 'dynamic' account, such as Tooley (1997) and Button (2006). As Pezet notes, Tooley also employs the 'as of' modification but this still renders

[110] It might be argued that in Pezet's rendition $\exists_{As}$ also appears to be functioning as a restricted quantifier.

change in terms of the relativisation of *permanent* facts to their *temporal locations* and, in this sense, it is not significantly different from the temporal variation of the eternalist. A key characteristic of metaphysical change is that the temporal, or dynamic, aspects of reality should be *internalised* rather than made relative to an external, B-series time, and it is this that will be used later in providing a definition of change suitable for the Existence Presentist.

Therefore, the second criterion for a suitable account of change is that it is consistent with 'real', metaphysical change rather than merely temporal variation:

> (D2): The definition of change is consistent with 'real' metaphysical change (C_M).

5.3.3 Taking Tense Seriously Implies that there is Metaphysical Change

Having established two criteria for a suitable account of change and persistence, given the commitments (EP and RS) of the compatibilist presentist, in the remainder of this chapter I develop these accounts. Prior to this, I follow on from the suggestion made in the previous section that the 'serious' presentist should subscribe to the thesis of metaphysical change. This was motivated by the intuition that metaphysical change is that feature of reality that is captured by tense. Here I provide an argument for a more formal connection, namely, that metaphysical change is implied if reality is objectively tensed.

The 'serious' presentist, i.e., the presentist who also 'takes tense seriously', subscribes to the view that reality is objectively tensed; this is the view that:[111]

> (T1): Reality exemplifies passage: for all concrete entities, α, α *is* present implies α *was* future and *will be* past.

[111] It is accepted that the scope of T1 does not apply to the existence of the first and last moments of a finite universe, if that universe is created from nothing and annihilates to nothing. However, such a position generates serious metaphysical problems of its own. Under an alternative, multiverse theory (such as that propounded by Mersini-Houghton, 2008) the first and last moment of our universe may be seen as having a causally grounded 'past' and 'future', but in the sense of 'states', rather than 'times'.

Under Existence Presentism (§ 4.8) an identity is asserted between existence and presence, and so all that exists is necessarily present:

(T2): The whole of what exists is present

From T1 and T2 it follows that:

(T3): The whole of what exists *was* future and *will be* past

A definition of change appropriate to a compatibilist account of Existence Presentism will be provided in § 5.8. In advance of this, it merely needs to be noted that change, for the reasons given above, needs to be formulated independently of B-series time. It also appears that some form of incompatibility condition seems essential to change, together with a notion of transition. In advance of further analysis, the following is offered as a working description of change, although it is admittedly short of being a definition:

(T4): Change involves transition between incompatible states.

From (T3) and (T4) it can be seen that the thesis of metaphysical change follows:

(T_M): The whole of what exists is changing.

The thesis of metaphysical change is therefore implied under any presentist account that, like Existence Presentism, takes tense seriously.

5.4 The Unsuitability of the Standard Accounts of Persistence

I describe in this section how the standard accounts of persistence fail to meet the proposed desiderata since both are underpinned by the B-series time of eternalism. I then consider claims that a strictly tensed approach to endurance (e.g. Zimmerman, 1998, Haslanger, 2003 and Baron, 2018) might work for the presentist. Arguments from both Tallant (2018) and Lowe (1998) suggest that these fail. The assumption that persistence should be underpinned by transtemporal identity is the source of these problems. Consequently, an alternative ground for persistence needs to be established.

5.4.1 The Unsuitability of Perdurantism for the Presentist

Perdurantism, while it offers 'neat solutions to metaphysical problems' (Ingthorsson, 2009, p. 4), is unsuitable for the compatibilist presentist. This is because it satisfies neither of the criteria, D1 and D2. In what follows I use Tallant's arguments to show that perdurance is contrary to D1, since it implies the existence of non-present times. I then argue that perdurance is also incompatible with real, metaphysical change (D2).

Perdurantism, at first glance, certainly appears to run counter to presentism.[112] Since, under presentism, the past and future do not exist there can be no other temporal location available for different temporal parts to occupy. Indeed, notable presentists, such as Prior (1958), Geach (1972) and Chisholm (1976) reject the notion of temporal parts. Tallant (2018) provides an argument to support this conclusion on the basis that perdurance commits the presentist to 'transtemporal identity dependencies' for which they lack the requisite ontological bases.

Tallant argues that under perdurance the identity of the persisting whole depends upon its having each of the temporal parts as a mereological part. Tallant's argument utilises a notion of identity dependence from Lowe, outlined in Tahko and Lowe (2016), that is defined as follows:

> x depends for its identity upon y $=_{df}$ There is a function f such that it is part of the essence of x that x is f(y) (2016, § 4.2).

In the case of perdurance the candidate function, f, is 'having y as a (temporal) part'. Since not all of the temporal parts are presently existing, the persistent whole can at most be the sum of what presently exists. Yet the temporal part that presently exists changes with time and, as a consequence, 'there is no persistence over time, since the identity of the sum changes over time' (Tallant, 2018, §3.1). Non-existent temporal parts cannot, for Tallant, constitute the

[112] Nonetheless, attempts have been made to combine presentism and perdurantism. Brogaard (2000) attempts such a feat: objects persist by possessing temporal parts but each only exists in the present moment. Lombard (1999) adopts a similar approach. Benovsky (2007) objects that a persisting entity cannot be composed of non-existent temporal parts.

identity of an *existing* sum. He illustrates this with the example of a heap of stones: the identity of the heap, *qua* mereological sum, can only be fixed by those stones that exist, and that are parts of the heap.

Tallant anticipates a counter-argument that relies upon asserting a distinction between temporal and spatial wholes.[113] This argument claims that temporal wholes can be distinguished from spatial wholes in virtue of the fact that they are *not* dependent upon the existence of each of their (temporal) parts. Tallant accepts that a distinction *can* be drawn between temporal and spatial parts, but that this is irrelevant to the argument. His argument centres on the dependencies in play between mereological parts and wholes, irrespective of the nature of the whole. It is in the nature of a mereological whole that its identity is determined by the existence of its parts and this is true irrespective of whether one considers, for example, spatial parts, 'conceptual parts', 'spiritual parts' or 'logical parts' (*Ibid*, §4.4). If Tallant's argument succeeds, perdurantism is unsuitable for a compatibilist presentist model since it implies the existence of times other than the present.

Perdurantism is also incompatible with real change. Real change, as represented by the thesis of metaphysical change (C_M), requires that the *whole* of what exists is objectively and continually changing. Under perdurance, the problem of temporary intrinsics is resolved by rendering the object into distinct temporal parts, each of which possesses an incompatible intrinsic property. As a consequence, the object, as a whole, does not possess its (incompatible) properties and so it is not the object, as a whole, that changes *its* shape. Under perdurance, change is, rather, temporal variation; change just is different entities (temporal parts) possessing different, incompatible properties.[114]

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[113] For example, Brogaard's (2000) argument relies upon such a distinction.
[114] It is conceded that this criticism is applicable only where perdurantism is combined with eternalism. Some (e.g., Lombard, 1999 and Brogaard, 2000) have argued that perdurantism can be compatible with presentism. Lombard argues that events (which presumably should be accommodated within a presentist ontology) are temporal parts. If the present consists wholly of temporal parts this is compatible with real, metaphysical change since the whole of what exists is changing, as the different temporal parts come in and out of existence. However, events exist by *occurring* and are thereby *themselves* changes, rather than existing as persisting entities that undergo changes. Such a presentist perdurantist model could arguably not account for persisting entities that undergo changes.

Lombard (2010) regards this as 'simulated' change, in the way in which a series of still photographs simulates change. The temporal parts, of themselves, are essentially changeless components. If perdurance is combined, as it frequently is, with a tenseless view of time, change is reduced to a conjunction of changeless entities: change becomes mere (temporal) variation. As Mellor (1998, p. 71) notes:

> If a poker is hot at 2.15 and cold at 3.15, then those always were and always will be its temperatures at those times […] So if, as everyone agrees, coexistence rules out change in the spatial case, how can it be compatible with change in time?

Perdurance therefore fails to meet both criteria, D1 and D2, for a suitable account of persistence under a compatibilist presentism.

5.4.2 The Unsuitability of Endurantism for the Presentist

Endurantism is undoubtedly the model of persistence that is most naturally associated with presentism (and indeed any tensed theory of time)[115] in the sense that things are wholly present whenever they exist. Presentism makes it easier to preserve what Haslanger (2003) refers to as the 'proper subject condition' of endurantism. This is the intuition that it is the *whole object* that possesses its associated properties and the whole object that both changes and persists. Despite this, it is argued here that endurantism, though often seen as the natural bedfellow for presentism, also satisfies neither D1 nor D2.

Tallant's (2018) argument, considered above, also extends to endurantism, which means that endurantism fails to satisfy D1 because it commits the presentist to the existence of non-present (B-series) times. Under endurantism, persistence is given by numerical identity *over time*: any object is wholly present at each time at which it exists. This being so, Tallant applies Lowe's notion of identity dependence once again. In this case, he argues, the relevant

[115] Carter and Hestevold (1994), Loux (1998), Lowe (1998), Benovsky (2007) and Baron (2018) maintain such a stance. Merricks (1999) provides an argument that the existence of enduring objects implies presentism. This does not mean, however, that presentism implies an endurance account of persistence.

function, f, for endurance has to be '*being an existent at times other than t*' (*Ibid*, § 3.3). Since persistence is distinguishable from instantaneous existence, the identity of the persisting entity, *qua* persisting entity, is consequently (identity) dependent upon the existence of the whole entity at multiple times. Existence at multiple times is incompatible with presentism and, therefore, so is endurantism.

Tallant further maintains that the presentist strategy of employing presently existing surrogates as the relevant truthmakers for past tensed claims is of no help in rehabilitating endurance. This is because presently existing surrogates exist only in the present, yet endurance, construed as *transtemporal* identity, requires temporal location at more than one time. The identity of a present object is dependent upon its being wholly present at each time at which it exists; yet, for the presentist, there *is* no other temporal moment at which an object is wholly present other than the present moment.

The second problem is that endurantism is also incompatible with real change, and so fails to satisfy D2. As perdurantism temporally indexes the object, so endurantism temporally indexes properties, in order to avoid the problem of temporary intrinsics. Under endurantism, the candle is considered 'straight-at-t' rather than just straight *simpliciter*.

This temporal relativisation of properties, although preserving numerical identity, means that an entity has all its temporally-indexed properties at all times. As Seibt (2007) notes, this means that the candle is always straight-at-t1 and bent-at-t2. This runs contrary to the requirement of providing for real change. Assume that t2 is present. To provide for real, metaphysical change endurance must account for the fact that *now*, at t2 (and no-when else), the whole candle *is changing*. Yet there appears to be nothing to which the endurantist can appeal in order to do this. The endurantist cannot appeal to a difference in the candle's properties since the properties it possesses now (being straight-at-t1 and bent-at-t2) are identical to those it had at t1 even though it was not changing at t1. It appears that the very mechanism introduced to avoid a contradiction between identity and change (temporal indexation) preserves numerical identity at the expense of real change since the incompatibility condition of change is lost. If there is no incompatibility in properties with which to appeal, it is unclear in what respect the whole of what exists (assuming there is just the candle) can be said to be changing.

To conclude, both endurantism and perdurantism fail to satisfy each of the requirements on an appropriate account of persistence for the compatibilist Existence Presentist. Both commit the presentist to the existence of times other than the present and both are inadequate in accounting for 'real' metaphysical change.

5.4.3 The Underlying Problem – an Eternalist View of Time

Tallant's (2018) argument works against both endurantism and perdurantism because it targets the common central assumption that persistence is *identity over time*. This assumption conflicts with presentism because it requires transtemporal identity dependencies to hold: these, in turn, imply the existence of times other than the present. Both models of persistence are therefore underpinned by the B-series time of eternalism and this is why neither can provide a suitable account of persistence for the presentist.

Hinchliff (1996) argues to a similar conclusion: it is the assumption of an eternalist view of time, common to both endurantism and perdurantism, that gives rise to the problem of temporary intrinsics. The possession of incompatible properties by one and the same entity only *appears* to give rise to a contradiction where all times are considered to be ontologically on a par. Change is the possession of incompatible properties at different times. However, if those different times are ontologically indistinguishable, and exist on a par, then one and the same object possesses incompatible properties, and a contradiction ensues. Indeed, it was Lewis (1986a, p. 204) himself who originally conceded that presentism does not, as such, suffer from the problem of temporary intrinsics. No contradiction arises for the presentist since 'the only intrinsic properties of a thing are those it has at the present moment', and so the possession of incompatible intrinsic properties just does not arise. Nonetheless, Lewis' fatal blow is that the presentist escapes the problem of temporary intrinsics precisely because they fail to allow for persistence *at all* and this is because presentism does not allow for different times at which entities can be wholly present.

Such problems reinforce the requirement that a presentist model of persistence should be formulated independently of B-series time (criterion D1), in order to avoid a commitment to times other than the present. Further, if by ‘taking tense seriously’ the presentist does circumvent the problem of temporary intrinsics, as Hinchliff (1996) suggests, this indicates the potential route to achieving an appropriate account of persistence, one that is completely independent of B-series time. Indeed, it is sometimes claimed that by ‘taking tense seriously’ the presentist *can* account for both persistence and ‘real’ change, and such claims will be reviewed in the following section. I argue that these approaches are unsuccessful because they fail to achieve complete independence from B-series time, and this is rooted in a failure to abandon the notion that persistence should be grounded in transtemporal identity.

5.4.4 No Problems for the (Serious) Presentist?

There are several responses to Lewis’ (1986a) claim that the presentist, although not succumbing to the problem of temporary intrinsics, cannot account for persistence. The strategies have in common a focus on formulating persistence in strictly tensed terms.

Zimmerman (1998) counters Lewis’ charge against presentism by arguing that persistence does not require the existence of more than one time, but only that other times *will exist* and *did exist* at which the entity will be, or was, wholly present. Thus, the candle *is* wholly present now, *was* wholly present at a prior time and *will be* wholly present at a future moment. This is how he sees the (serious) presentist as accounting for persistence. Similarly, Haslanger (2003) challenges the claim that the presentist is ontologically under-resourced to provide for the persistence of the candle. Such a position, she argues, merely begs the question against the presentist by assuming that a tenseless framework is required to provide the necessary truthmakers: ‘The fact that the candle was straight is a present (past-tensed) fact about it’ (2003, p.340).

This approach, as it stands, still falls foul of Tallant's argument (§ 5.4.1). The argument is that the presentist cannot account for persistence, even using tensed truthmakers, when persistence is defined in terms of *transtemporal identity dependence* (as it is under both standard models). This is because *any sort* of identity dependence requires that the constituents of that dependence relation are existent entities:

> my concern is that there is a trans-temporal identity dependence: a dependence of the present object upon the past. Identity dependence consists in there being a function that takes (at least) one entity as an input and generates an output. Lowe's (2010: §4) example is a useful reminder: the function 'being the marriage of' takes an input from two (existing) people and gives us the identity of the marriage. Simply, then: what kind of function is saturated by a now past, non-existent entity? There is no obvious response. (Tallant, 2018, § 4.2)

The transtemporal identity function at work under the standard models of persistence serves to locate the persisting object at multiple times. Tallant does not disagree with Haslanger's point that this assumes an eternalist framework: rather, it is precisely this that makes both endurantism and perdurantism incompatible with presentism.

> Endurance (e.g.) analyses persistence as a matter of O's being wholly present at a range of times. It does not analyse persistence in terms of it being true that *O was wholly present* at a range of times. (Tallant, 2018, § 4.1)

Tallant's argument indicates that seeking to adopt a tensed formulation of either endurance or perdurance, as they stand, will be unsuccessful. What seems to be required is a completely *different* formulation of persistence, one that is, nonetheless, consistent with an objectively tensed reality. This is the approach attempted by Baron (2018).

Baron (2018) suggests that Tallant's argument itself assumes a tenseless (or 'locative') definition of endurance ('wholly located at a range of times, t') as well as a tenseless rendition of Lowe's identity function. By rigorous application of a tensed approach to both, Baron argues that transtemporal identity can be made consistent with a model that is endurantist in spirit. He redefines endurance in tensed terms (which he refers to as 'tensed locative endurance', TEL):

> An object O endures from the past to the present iff O is wholly located in the present and either O was wholly located at some time in the past when that time existed or O will be located at some time in the future when that time comes into existence. (2018, p.5)

He argues that this is consistent with Lowe's concept of identity dependence, provided the latter is given in terms of a tensed function (f*) which *had* as an argument a past entity when that entity was present, rather than, on a tenseless construal, constraining the presentist to locate a past time to stand as the argument in the function:

> In short, then, the nefarious presentist can say the following: an entity endures when it has a location now (by f∗) and had a location in the past (by f∗), where this latter fact is delivered by the nefarious strategy of cheating[116] (2018, p.9).

Since, under Baron's redefinition of endurance, a persisting object is not located at multiple times, the non-existence of past times has no impact on the effectiveness of Lowe's function. Here, Lowe's function takes only the present time, rather than multiple times, as an argument and so does not succeed in locating the object at multiple times. Yet it succeeds in capturing the sense in which persistence involves being wholly located at each moment at which an object exists.

Although Baron's strategy appears to bypass the difficulties presented by Tallant's argument, he maintains the core tenet of the standard accounts that persistence has to be provided by transtemporal identity. Consequently, it is not

[116] The 'nefarious strategy of cheating' (after Tallant and Ingram, 2015) refers to grounding (or constituting) facts about the past 'in virtue of' how the past was, in a non-ontologically committing manner. Thus, facts about the past (and, similarly, singular propositions) are constituted by entities that *used* to exist, but do not exist *now*.

clear that his formulation of persistence can succeed; I provide the reasons for this in the following section.

5.4.5 The Need to Abandon Transtemporal Identity

The assumption that persistence is numerical identity over time lies at the heart of the problem of temporary intrinsics, as noted in § 5.2. This assumption can be traced to the, now definitive, quotation from Lewis which provides the standard notion of persistence:

> Let us say that something *persists* iff, somehow or other, it exists at various times; this is the neutral word: Something *perdures* iff it persists by having different temporal parts, or stages, at different times [...] whereas it *endures* iff it persists by being wholly present at more than one time (1986a, p. 202)

According to Lewis, persistence, as the '*neutral* word', assumes that one and the same continuant exists '*at* various times', and so implicitly assumes that persistence has to be a matter of some kind of transtemporal identity dependency. Accounting for persistence thereby becomes a binary choice between endurantism and perdurantism, which, as we have seen, prejudices, at the outset, the development of a suitable presentist account of persistence.

It is the notion of existence 'at various times' that is unsuitable for the Existence Presentist, even when formulated in strictly tensed terms, as attempted by Baron. Baron's definition of 'tensed locative endurance' (§ 5.4.4) maintains the concept of transtemporal identity dependence in so far as O's continuing identity depends upon its 'being wholly located in the present' *and* having been 'wholly located at some time in the past when that time existed' (Baron, 2018, p.5).

As noted previously (§ 5.3), for the Existence Presentist the present is independent of any, and all, B-series times. The present is not a B-series time. On the assumption that the Existence Presentist also subscribes to objective temporal passage, this implies that neither the past nor the future can be constituted by B-series times that previously existed, or are yet to exist, respectively. If they were, temporal passage would equate to the movement of the present along such a series of B-times, in a manner akin to the Moving Spotlight model (as described by Broad, 1923, p.59); yet this is not a model to which the Existence Presentist does, or can, subscribe.[117] If the past is not a time, or set of times, that previously existed then a presently existing entity cannot, contra Baron (2018, p.5), have been 'wholly located at a time in the past when that time existed'. There was nothing at which an entity can have been located and so the persistence of an entity from past to present cannot be based upon a prior temporal *location*, however strict the tensed construal of that location.

There is a further argument from Lowe which suggests that Baron's approach cannot succeed. Lowe (1998, pp. 110-114) questions whether persistence (as endurance) can be successfully accounted for in terms of transtemporal identity. Transtemporal identity, as continuing identity through time, grounds the identity of an entity in spatiotemporal continuity. Lowe argues that spatiotemporal continuity is not sufficient to provide an identity criterion for, say, one given tomato, as opposed to two distinct tomatoes that occupy the same spatiotemporal area, without *presupposing* that the instantiation refers to one and the same tomato. In other words, spatiotemporal continuity presupposes the identity conditions it is seeking to describe. Lowe anticipates the potential retort that the impenetrability of material objects provides the means to distinguish the two cases. He argues that the impenetrability of material objects *itself presupposes* that the object concerned is a persisting entity. Impenetrability arises because concrete objects are material objects, and matter excludes other matter from occupying the same spatiotemporal region. The capacity for impenetrability thus arises only in virtue of the fact that material objects *are* persisting entities: 'only a thing of a persisting kind can exercise a capacity to exclude another thing from the place it occupies' (2001, p.

[117] Under the Moving Spotlight Model, the present is seen as a property possessed by an objectively privileged moment of time. The present changes by the movement of this property along a series of times in a manner similar to a 'moving spotlight' which shines a light on the given, privileged moment of time that denotes the present. As such, the model succumbs to McTaggart's argument where temporal change conceived as movement relative to B-series indices generates either contradiction or vicious infinite regress.

113). Consequently, the capacity for impenetrability cannot underpin the identity of the object without circularity, and it is not clear what other potential candidates there might be. This leads Lowe to conclude that continuing identity is primitive (2001, p. 121-125).

Lowe's argument is significant because it is a more general argument that persistence cannot be grounded in transtemporal identity, at all, without circularity. The focus of Tallant's argument is that both endurance and perdurance (because they rely upon transtemporal identity) commit the presentist to non-present times. Rather than accepting that there is no model of persistence compatible with presentism, Lowe's argument suggests we should challenge the assumption that persistence has to be given in terms of transtemporal identity. If an appropriate formulation of persistence is not to be underpinned by transtemporal identity dependencies, the presentist requires alternative grounds on which to construct an account.

In locating an alternative ground for persistence, it is apparent that the presentist should maintain a strictly tensed approach since, by doing so, they avoid the problem of temporary intrinsics. This leads to the thought that the presentist should look to the objective correlates of tense to provide the requisite grounds upon which to model both persistence and real, metaphysical change. This line of enquiry is pursued in the following section.

5.5 The Objective Correlates of Tense

Identifying the objective correlates of tense requires a clear analysis of the notion of objective passage as the starting point.

For the serious presentist that which exists is present, but also, that which exists *was* future and *will be* past.[118] What *is* present is therefore *transient* or temporary. This, by itself, however, is insufficient to characterise objective passage. If the present were *just* characterised by transience this would be consistent with the present being instantaneous. Yet the present is not instantaneous; an instantaneous present would not exhibit objective passage.

[118] Excepting first and last moments.

Rather, the present (as existence) itself *continues on* and, in doing so, it also exemplifies an essential continuity. This suggests that the concept of objective passage actually encompasses *two* different aspects of reality: the present exemplifies *both* transience and continuity. That which exists (and so constitutes the present) is transient, but the present (as existence) *itself* continues on. The objective correlates of tense are therefore twofold: *transience* and *continuity*. It is through the combination of these two aspects of reality that the present is intrinsically dynamic, it is in this way that the present 'flows'. The challenge for the presentist is therefore to construe these two objective correlates of tense (and so objective passage) independently of B-series time, and so *internalise* them within the present.

If transience and continuity are accepted as the objective correlates of tense then, at first glance, there is an intuitive alignment between persistence and continuity, on the one hand, and real change and transience, on the other. In the following sections I develop the case that this alignment permits the presentist to reformulate both persistence and change, in strictly tensed terms, so as to satisfy the original criteria, D1 and D2. Doing so succeeds in internalising the dynamic aspects of reality (indicated by tense) and so provides an account of objective becoming which does not succumb to the usual McTaggartian problems of contradiction and infinite regress (§ 1.4).

5.6 A Reformulation of Persistence

In this section I follow Lowe (1998) in adopting the position that continuing identity is primitive. I argue that this allows persistence to be construed in a manner that aligns with one of the objective correlates of tense, namely, continuity.

Abandoning the notion that persistence is provided by transtemporal identity, or identity over time, does not mean that we should forgo a strictly tensed-based approach towards an adequate conception of persistence. In particular, I suggest that the following might be offered as a starting point:

> P1: An object *O* persists iff *O* is present and either, *O* was past, or, *O* will be future

This meets criterion D1 in that it is formulated independently of B-series time and so is consistent with Existence Presentism. It is also consistent with the commitments of the 'serious' presentist, the presentist who subscribes to the view that reality is objectively tensed. What the formulation lacks, though, is something that guarantees, or grounds, the continuing identity of *O* from the past to the present, or from the present to the future.

I follow Lowe's lead in adopting the position that continuing identity is primitive; this would seem to make sense for the Existence Presentist. Such a presentist cannot define continuing identity in terms of B-series times, and Lowe's argument further suggests there are no other candidates to feature in the definiens. If continuing identity is primitive it does not, however, follow that there is nothing more to persistence, or that persistence is ungrounded.

The initial attempt at a strictly tensed construal of persistence given above (P1) indicates that, for the 'serious' presentist, persistence is grounded in the fact that reality is objectively tensed. Since, under Existence Presentism, an identity is asserted between presence and existence it follows that P1 can be restated as:

P2: An object *O* persists iff *O* exists and either, *O* existed, or, *O* will exist

If the continuing identity of *O* is taken as primitive, or ungrounded, then the *O* that presently exists is numerically identical with either the *O* that has existed, or, the *O* that will exist. In which case we can expand on P2 and state that the persistence of *O just is* its continuing existence. This suggests that a suitable definition of persistence under an Existence Presentist account is as follows:

Def_{PS}: Persistence $=_{\text{def}}$ continuity of existence

This reformulation of persistence is both consistent with Existence Presentism and captures what is intuitive under the endurance model. It expresses the notion that it is the whole entity that is temporally continuous, without requiring existence *at* different times. The continuing existence of entities does not require them to be located with respect to any external time series. To this extent Def_{PS} is also suitable for a compatibilist model of Existence Presentism that denies a place in its ontology for external, substantival time, but one that views B-series time, in reductionist terms, as the structure of reality.

Def_{PS} also avoids the principal disadvantage of endurantism. In § 5.2 it was noted that, in order for entities to exist wholly and completely at each of the many times at which they exist, endurantism requires temporal movement, or passage. It is difficult to formalise this other than as movement with respect to B-series time, and this embroils the presentist in McTaggart-style problems of contradiction or vicious regress.

In § 5.5 I argued that the objective correlates of tense are *transience* and *continuity*. Formulating persistence as continuity of existence not only provides a means of providing for persistence in strictly tensed terms (independently of B-series times), it also aligns persistence with one of the two objective correlates of tense: continuity. Construing persistence as continuing existence therefore also ensures that one of the temporal aspects of existence (associated with objective passage) becomes internalised, rather than indexed against an external, B-series time. This also makes sense for the Existence Presentist; that which exists *persists* in the present and it does so, not by existing at different times, but by *continuing* to exist in the present. For the Existence Presentist this is a strictly tensed construal of persistence.

If persistence aligns with one of the objective correlates of tense this would suggest that real, metaphysical change should be grounded in the other, namely, transience. That which exists undergoes real, metaphysical change in the present and, if metaphysical change is also to be formulated independently of B-series times (in other words, internalised in the present) then the notion of transience potentially provides the mechanism to achieve this. The following sections will be concerned with developing a suitably compatible model of change.

5.7 Towards a Suitable Account of Change

The standard accounts of persistence adopt a common conception of change (as noted in § 5.2): namely, that change is the possession of incompatible intrinsic properties at different times. This assumption, together with a shared, Lewisian, view of persistence (as 'existence at various times') underpins the problem of temporary intrinsics. Such an account of change is not suitable for the presentist.

The guiding principles for a suitable account of change, D1 and D2, require that change is characterised independently of B-series time, and that its formulation is consistent with the thesis of metaphysical change (C_M). In addition, § 5.3.3 indicates that the thesis of metaphysical change is implied by the position that reality is objectively tensed. This suggests as an initial hypothesis that, as with persistence, a suitable formulation of change for the presentist is one underpinned by the fact that reality is objectively tensed. The route to providing a satisfactory definition of change requires several steps. First, I distinguish the semantic from the metaphysical problem of temporary intrinsics and suggest a semantic solution that does not entail unsatisfactory metaphysical consequences for the presentist. This solution permits the presentist to circumvent the metaphysical problem. Understanding how this mechanism works confirms the hypothesis that real change is underpinned by 'transience', one of the two objective correlates of tense. In particular, equating an objectively tensed reality with one exemplifying continual creation and annihilation allows real, metaphysical change to be formulated independently of B-series times, and so internalised within the present.

5.7.1 The Semantic versus the Metaphysical Problem

The definition of change assumed within the standard models of persistence incorporates the idea that change depends upon, or occurs in, time, and seems to be a deeply entrenched notion. This is, I think, in part due to our reluctance to abandon the classical, Newtonian picture of reality, which retains its strongly intuitive appeal in our day to day lives, despite scientific evidence that it is not true. This is further supported by the mathematical representation of change within scientific theory. It is clear that we *describe* change, in subject-predicate terms, as incompatible properties at different times. However, the presentist needs to distinguish the semantic problem of change, concerning how change is modelled or *described*, from the metaphysical problem of what change is *ontologically*.

The need to draw a distinction between change, as it is ontologically, from the way in which change is described, or modelled, is supported by Lowe's (1998) distinction between the semantic and the metaphysical problem of temporary intrinsics. The semantic problem concerns the potential contradiction that arises from the logical form of sentences used to ascribe temporary intrinsic properties to persisting subjects. Such statements take the form '*a* is *F* at t1' and '*a* is *G* at t2' where *F* and *G* are incompatible predicates ascribed to one and the same object, *a*. The metaphysical problem, in contrast, concerns the matter of *how reality is* such that we can ascribe change (as the possession of incompatible properties) to objects without contradiction.

Change construed (metaphysically) as different properties at different (B-series) times is not only unsuitable for a presentist account, it is also incompatible with our best physical theories. The problem of time in quantum gravity (Chapter 2) suggests that strict adherence to background independence presents severe problems for the idea of time as something external and substantival. Instead, I argue (§ 2.6.4) that a reductionist structuralist account of time[119] provides a better fit. This means that change and physical evolution, construed as different properties, or physical observables, at different times are ruled out. Even the static, B-series conception of change is compromised precisely because 'no genuine physical magnitude takes on different values at different times' (Earman, 2002, pp. 2-3). This already provides an indication that change needs to be fundamentally re-modelled, in a manner that achieves independence from B-series time, and this can only benefit a compatibilist account of Existence Presentism. By adopting a reductionist model of B-series time, the presentist can accept the reality of B-series relations and agree that the B-series (as the time of science) is sufficient for *modelling* and *predicating*

[119] The proposed reductionist structuralist account regards spacetime as the structure of an objectively dynamic reality, at a fundamental level this is constituted by a dynamic energy-momentum field. It is argued in Chapter 2 that this provides the best interpretation of GTR to resolve the problems presented by Quantum Gravity.

'real' change. Yet, they can also maintain that this is not what change is *ontologically,* or objectively in the world.

The first step in formulating a suitable account of change is to adopt an alternative solution to the *semantic* problem of temporary intrinsics, one that has a better metaphysical alignment with presentism. This is the subject of the following subsection.

5.7.2 'Is-at-t': The Appropriate Solution to the Semantic Problem

Of Lewis' three proposed solutions to the semantic problem of temporary intrinsics, Lowe considers '*a* is-at-t *F*' (Lewis' solution (ii)) as the one best able to avoid embroiling 'the semantics of common-sense talk in metaphysical controversy' (2001, p.133). He sees the endurantist and perdurantist solutions as 'revisionary' with respect to predicates and 'revisionary' with respect to subjects, respectively.

In what follows I suggest that the 'is-at-t' solution provides a better metaphysical alignment with a tensed conception of reality; it also allows the presentist to circumvent the metaphysical problem of *how* reality is, such that we can ascribe change to objects (as the possession of incompatible properties) without contradiction. Understanding how this is achieved suggests the route to an appropriate formulation of change.

Lowe (1998, p.133) interprets the 'is-at-t' solution in terms of a two-place relation between the 'having of a property' and a 'time'. This interpretation, however, is not suitable for the Existence Presentist; interpreting 'is-at-t' in terms of a two-place relation incurs a separation between the 'having of a property' and a given 'time'. This separation brings with it the implication that time is substantival which is unsuitable for all the reasons given previously.[120]

[120] These reasons (discussed elsewhere) are as follows. First, substantival time is unsupported by our best physical theories (§ 2.6) and so the presentist should avoid it on compatibilist grounds. Second, McTaggart-style problems arise when temporal movement or transition, characteristic of tensed reality, is represented as movement with respect to an external time (§§ 1.4.1 & 1.4.2). Third, since all change, necessarily, occurs in the present, change must be formulated independently of B-series time (§ 5.3.1, D1).

Consequently, formulating change with respect to an external, background time is to be avoided.

Since for the Existence Presentist the present is not a unique, B-series time (§ 4.8), 'is-at-t' *cannot* be interpreted as temporal indexation – as indexing the copula to an external, B-series time - in a manner analogous to the temporal indexation of subject and predicate under the standard accounts. Rather, 'is-at-t' requires a strictly tensed interpretation. As noted previously (§ 5.4.3), it is only by doing so that the presentist is able to avoid the contradiction of temporary intrinsics. A strictly tensed interpretation works purely on the basis that the 'having' of properties is a 'just having', or a 'having *simpliciter*'. The having of properties is therefore a case of primitive predication, instantiated only in the present: the candle 'just has' the property of being bent (now). Such primitive predication also applies to both the past and future cases, but in these cases it is modified by the relevant tense operator ('the candle just had straightness'). The strictly tensed interpretation of '*a* is-at-t *F*' must therefore be a relation of *instantiation* between the object, *a*, and a property, *F* (a 'having simpliciter'), contrary to Lowe's interpretation of a two-place relation between the 'having of a property' and a 'time'.

Interpreted in the manner described, 'is-at-t' represents the ontological privilege of the present: all properties, *F*, that can be attributed to *a* are all and only those properties it 'just has now'. In addition to avoiding contradiction, this approach allows the presentist to avoid the charge, levelled against endurantism, that temporally indexed properties are merely quasi-relations, rather than 'genuine', intrinsic properties.

This strictly tensed interpretation of the having of properties (a having *simpliciter*) indicates that, in addition to incompatibility, change involves a *transition* between incompatible states, a transition between '*a was F*' and '*a is ¬F*'. The next step is to consider how such a transition can be modelled independently from B-series time.

5.7.3 Change as it is in Reality

I argued above that qualitative change involves a transition between incompatible properties: '*a was F*' and '*a is ¬F*'. By considering some examples of such change it becomes apparent that this transition can be considered solely as a *gain* or *loss* of properties, in other words as a gain or loss *simpliciter*. Consequently, for the presentist, qualitative change should be construed as the gain or loss of properties *simpliciter*, rather than as the possession of properties at different times.

Consider, as a concrete example, the change in colour of the Statue of Liberty from bronze to green. At the physical level, this is the result of an interaction between the copper metal constituting the statue and oxygen from moisture in the air to form a pale green patina of copper oxide. Another example is the lit candle that, in melting, becomes bent over time. The latter involves an exchange of energy, in the form of heat from the flame, which results in a melting of the wax. In each case the change, although *described* in qualitative terms as incompatible predicates at different times, *as it is in reality* involves some form of causal interaction which results in a *gain* or *loss* of properties. In the case of the Statue of Liberty, the statue *gains* the property of being green (from the layer of copper oxide). In respect of the candle, the candle *loses* the property of solidity and *gains* properties of liquidity and viscosity.

This seems true for all cases of qualitative change as they are in reality; they involve a gain or loss of properties *simpliciter.* Further, the transition represented by this gain or loss is, in some manner, grounded in the fact that reality as objectively tensed exemplifies transience. I suggest that there is nothing, *pertinent to change*, that is not captured by modelling qualitative change in this way, rather than adopting the standard construal of change as the possession of different properties at different times. If this can be supported it provides a route to establishing a formulation of change independent of B-series time, in accordance with criterion D1.

Nonetheless, the analysis of change given thus far is incomplete since qualitative change, as a transition between incompatible *properties,* covers only one sort of change. Under qualitative change the whole entity changes *its* properties. Meincke (2019, p.15) highlights another type of change, which she refers to as '*substantial*' change. Substantial change involves *entities* coming into and going out of existence, in the manner in which 'events' (such as explosions) involve changes. Lowe (1998, p.122) similarly recognises these two different manifestations of change.

It is pertinent to note here that these two types of change mirror an opposition reflected in the standard accounts of persistence. Endurance appears better aligned with *qualitative* change, persisting entities change by possessing different, incompatible properties at different times. The statue which was copper-coloured changes over time to become green; the statue as a persisting entity changes its colour from copper to green.

In opposition, the temporal parts of perdurance more resemble events, in the sense of being instantaneous (or nearly instantaneous) entities that come into and go out of existence sequentially. Perdurance is thus better able to capture *substantial* change, as represented by the bang and flash of an explosion. To this extent both the standard accounts intuitively reflect different aspects of the nature of change. There is a natural tendency to consider objects as 'wholly located' in the present, whereas entities such as explosions have parts that are not yet present. We therefore have a tendency to refer only to 'wholly present objects' *as changing*, yet, it is equally the case that things such as explosions *are changes*.

An adequate account of change needs to reflect *both* these types of change. By providing this, the presentist can forge a 'third way' between endurance and perdurance, and establish an account that avoids the limitations of each (§ 5.4).

What is common to both types of change – qualitative and substantial – is that they involve a coming into and going out of existence; in the former case it is properties and in the latter, entities, and this indicates the mechanism required to internalise change and formulate it independently of B-series time. Some attempts have been made within presentist accounts to achieve this internalisation, and I describe these in the following subsection. Though these attempts fail they provide an insight into how change should be formalised under a presentist account and also how it is that real change aligns with the concept of transience, identified as one of the objective correlates of tense.

5.7.4 The Relevance of 'Transientism'

The difficulties encountered in modelling objective passage may account for why the dynamic character of existence is often not made explicit in presentist models. As Gołosz (2013, p. 55) suggests, the traditional formulation of presentism as 'only the present exists' can imply that existence is static in nature. Nonetheless, a sense that there is the need to incorporate the dynamic aspects of reality into presentism appears to underpin recent accounts developed by Deasy (2017) and Correia and Rosenkranz (2015).

For Deasy, any definition of presentism needs to include what he refers to as 'transientism':

> TRANSIENTISM: Sometimes, something begins to exist and sometimes, something ceases to exist
>
> (formally: $\mathbf{S}(\exists x\ \mathbf{P}\neg\exists y\ y = x)\ \&\ \mathbf{S}(\exists x\ \mathbf{F}\neg\exists y\ y = x)$) (2017, p. 390)

Transientism, in combination with the A-theorist's commitment to a privileged present, provides Deasy with his definition of presentism:

> PRESENTISM: There is an absolute, objective present instant (THE A-THEORY) & sometimes, something begins to exist and sometimes, something ceases to exist (TRANSIENTISM)' (p.391)

Along similar lines, Correia and Rosenkranz (2015) include a notion of being a 'one-off' (itself a conjunction of 'new' and 'doomed') as well as a concept of being 'in time', in their definition of presentism:

> Let us say that m is new iff always in the past, m does not exist, that m is doomed iff always in the future, m does not exist, and that m is in time iff sometimes, for some time t, m is contemporaneous with t. (2015, p. 22)

Their definition of presentism is consequently:

> Always, $\exists t$(t is one-off & $\forall x$(x is in time $\rightarrow$ x is contemporaneous with t))
> (*Ibid*, p.24)

Common to both the accounts is the sense that, for the presentist, existence is transient or temporary.

Tallant (2019) argues that, as formulations of presentism, these two models ultimately fail. In the case of Deasy this is because his model is compatible with scenarios that presentists would not accept. One of these Tallant describes as the 'trundling block' universe (*Ibid*, § 2). This is a modification of the growing block universe, which, after 1000 years, starts to lose the initial events (at the rear of the block) at such a rate that maintains its size whilst new events are constantly added to the 'front edge' of the block. Although this scenario satisfies Deasy's definition it is unacceptable to the presentist, and it is unacceptable because it allows for the existence of past objects: individuals such as William the Conqueror (who died in 1087) still exist in the 'trundling block' universe and so instantiate presentness.

What is important here is not so much the possibility of counter-examples it is *why* Deasy's model fails as a statement of presentism; it fails because it is underpinned by B-series times. The 'Sometimes' temporal operator (**S**), in the definition of transientism, quantifies over B-series instants of time at which things come into and go out of existence. By indexing existence to 'times' it renders the present a defined B-series interval: in the case of Tallant's 'trundling block' example, an interval of 1000 years. In Chapter 4 it was concluded that the reason why Existence Presentism is the only formulation of presentism, to date, able to avoid Meyer's (2005, 2013) 'presentist's dilemma' is precisely because the present is freed from equation with any given (or unique) time. A similar objection applies to the formulation given by Correia and Rosenkranz (2015); existence is existence at a particular B-series time ('x is in time') and the present is conceived of as a hyperplane of simultaneity ('x is contemporaneous with t').

Despite this, the motivation behind both attempts, namely, to incorporate the idea that the present is transient and so continually changing, is a sound one.

The models fall short in so far as they *externalise* the dynamic aspects of reality (to an external time) rather than *internalising* them.

Transientism, though it cannot be used to define presentism, does suggest a mechanism for aligning the notion of change as it applies to an objectively dynamic present, with change as it applies to the entities that comprise the present (described in § 5.7.3). A simple modification is required in order to ensure that change is internalised and modelled independently of B-series time.

5.8 Formulating Change for the Presentist

An appropriate definition of change, for the 'serious' presentist, has to be one that is consistent with 'real', metaphysical change (criterion D2), described by the following thesis:

(C_M): The whole of what exists is changing

As previously suggested the thesis of metaphysical change is important in distinguishing the presentist's account of change from that of the eternalist. The eternalist *externalises* the dynamic, or temporal, aspects of reality by defining change as relative to, and metaphysically dependent upon, an external, B-series time. The thesis of metaphysical change is an expression of a position that regards the dynamic aspects of reality as *internalised* and metaphysically independent of B-series time.

The dynamic aspects of reality (the objective correlates of tense) are twofold: transience and continuity (§ 5.5). Since persistence (when formulated in strictly tensed terms) is the continuity of existence, it was suggested in § 5.6 that real, metaphysical change might be grounded in the other objective correlate of tense: transience. Transience (as described in § 5.5) reflects the temporary nature of that which is present: that which exists *has* come into existence and *will* go out of existence. In other words, transience involves a coming into and going out of existence. It has also been argued (§ 5.7.3) that change (both qualitative and substantial), as it is in reality, involves a coming into and going out of existence. This leads to the thought that real change, for the presentist, should incorporate the idea, also recognised by Lowe, that 'something begins to be the case which was previously not the case' (2001, p. 122). In other words, real change should be explicated in terms of creation and annihilation. Change, as it is metaphysically, involves the creation of something new (a property or entity) or the destruction of something existing, rather than the possession of incompatible properties at different times. This, then, provides the definition of 'real' change suitable for the compatibilist presentist:

> Def_{RC}: Real Change = $_{\text{def}}$ Something coming into existence and/or something going out of existence

This definition of real change (Def_{RC}) reflects what is insightful about Deasy's transientism but, importantly, it is a formulation that is not indexed to (B-series) times and so is acceptable to the Existence Presentist. It thereby satisfies both the original desiderata for a compatibilist account: it is formulated independently of B-series time (D1) and is consistent with metaphysical change (D2).

5.9 Characterising the Present

In this final section I argue that persistence and real change, as formulated, positively characterize the nature of the present. It will be seen (in Chapter 8) that this characterisation of the present provides a route to address a particular problem for the presentist namely, the asymmetry of fixity. I also argue, in what follows, that real change and persistence are metaphysically primitive, and this informs the ontological model required for a compatible account of presentism (Chapter 6).

5.9.1 The Nature of the Present

Under existence presentism, an identity is asserted between existence and presence, but this leaves open a further explication of the nature of presence. Tallant (2019, p. 409) notes, that several commentators charge presentists with failing to provide clarity on the meaning and role of 'presence' or 'presentness' within their models.[121] This criticism is addressed here.

The identity between existence and presence is a profound claim and one which implores further elaboration. It does not automatically follow that because existence (and therefore presence) is primitive it is not further explicable. The fundamental categories of our ontology are primitive but this does not mean we cannot further describe the features of those categories. Indeed, it is these that bear the definitional burden of those categories.

The formulations of persistence and real, metaphysical change given in this Chapter reflect how it is that reality, and so existence, is objectively tensed. In § 5.5 I argue that the objective correlates of tense are both *transience* and *continuity*. The formulation of persistence, as continuing existence (Def_{PS}, § 5.6), reflects *continuity*, whereas *transience* is reflected in the construal of real change (Def_{RC}, § 5.8) as absolute creation and annihilation. Since, for the Existence Presentist, presence is existence this picture of objectively tensed existence also provides a characterisation of the present. The nature of the present, as that which exists, is provided by the two objective correlates of tense: persistence and real, metaphysical change.

The definitions of persistence and real (metaphysical) change, provided above, reveal them to be opposing aspects of reality. Persistence, as a continuity of existence, and real change, as a coming into or going out of existence, are orthogonal features of reality. This opposition mirrors the opposing nature of persistence and change under the standard metaphysical models. Indeed, the problem of temporary intrinsics expresses precisely this issue: how it is that one and the same entity can both intrinsically change and yet remain identical? Nonetheless, this opposition belies an intimate connection between these two correlates of tense in characterising the present. The connection is this: the present persists, or continues on, *in virtue of* the constant creation and annihilation of entities that is given by real (metaphysical) change. In this

[121] For example, Deasy (2017), Correia and Rosenkranz (2015), Williamson (2013, pp. 24-25). Pezet (2017, p. 1835) also concedes that 'the presentist thesis is in need of supplementation with a worked out account of the A-determinations themselves'.

manner the 'flow' of the present is internalised, or self-generated, rather than externalised relative to a B-series time. The present is not dynamic by being a movement *in*, or *of*, time. The present is dynamic in so far as the whole of what exists continually changes through constant creation and annihilation.

This characterisation of the present brings two advantages for the presentist. It allows objective passage to be modelled without engendering McTaggart-style problems.[122] Secondly, it will be seen in Chapter 8 that the recognition that metaphysical change is an intrinsic feature of the present provides the presentist with the tools to account for the asymmetry of fixity between the past and the future.

5.9.2 Real Change and Persistence as Metaphysically Primitive

Since real change and persistence characterize the present, it would seem to follow that they are metaphysically primitive. In this subsection, I explicitly draw this out. It might be thought that adopting such a position would preclude the presentist from establishing a compatibilist model of presentism. Contrary to this, Chapter 6 will show that this is actually central to facilitating such an account, once an appropriate ontology has been formulated.

For the purposes of what follows I restate the definitions of persistence (§ 5.6) and real, metaphysical change (§ 5.8):

> $\mathrm{Def}_{\mathrm{PS}}$: Persistence $=_{\mathrm{def}}$ continuity of existence

> $\mathrm{Def}_{\mathrm{RC}}$: Real Change $=_{\mathrm{def}}$ something coming into existence and/or something going out of existence

Existence presentism formulates the present solely in terms of existence. I make the assumption here that the concept of existence is metaphysically primitive. By 'metaphysically primitive' I mean that it is ontologically ungrounded and that it does not reduce to any other concept.

Under the model proposed both real change and persistence are defined solely in terms of existence. More than this they comprise two different aspects of a

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122 McTaggart-style problems are discussed in Chapter 1, §1.6.1.

particular notion of existence, namely, concrete existence. In particular, persistence indicates the continuity, or on-going-ness of existence, whereas metaphysical change describes the transition into and out of existence. As such they describe contrary, or opposing, aspects of concrete existence. They are also mutually dependent. In order to persist, or continue to exist, concrete entities must come into existence and so persistence depends upon real, metaphysical change. On the other hand, in order to go out of existence an entity must already exist, and so be persisting. In this way real, metaphysical change depends upon persistence.[123]

If concrete existence is taken to be metaphysically primitive then, as aspects of existence, both persistence and metaphysical change must also be metaphysically primitive. Each is ontologically ungrounded and neither can be reduced to any further concept other than that of existence.

It will be revealed in Chapter 6 that it is in virtue of possessing these opposing, but mutually dependent, aspects that concrete existence is structured spatiotemporally, in the manner described by relativity theory. It will be argued that B-series relations arise from the structure of an objectively dynamic reality, one that exemplifies both persistence and real, metaphysical change – the objective correlates of tense.

I propose that concepts that are metaphysically primitive need to be represented in the categories of an underlying ontology. The task of Chapter 6 is therefore to establish an appropriate ontological framework for presentism that can demonstrate compatibility with physical theory and one that reflects a reality in which real change and persistence are metaphysically primitive: in other words, a reality that is objectively tensed.

[123] It might be countered that events (e.g., explosions) are archetypal concrete entities that only exemplify real change and not persistence. I would argue that any actual, concrete event always involves some (albeit indiscernible) temporal extension. This is further discussed in § 6.8 where I argue that events require persisting entities to interact and so, to this extent, real metaphysical change depends upon persistence.

CHAPTER 6 – AN ONTOLOGY FOR A COMPATIBILIST PRESENTISM

6.1 Introduction

I conclude in the previous chapter that real change and persistence are the objective correlates of tense, for the Existence Presentist, and that these are metaphysically primitive. By adopting this position, the presentist is able to internalise the dynamic aspects of reality, in other words, to formulate the objective correlates of tense independently of B-series time. Internalising the temporal aspects of reality requires an appropriate ontology, and this is developed in this chapter. In doing so the route to the compatibility of presentism with physical theory is established.

I consider the process ontological models of Rescher (1996) and Seibt (1997, 2007, 2009) and argue that though processes (as defined) exemplify persistence (through functional recurrence) change is construed as merely functional variation, rather than the real, metaphysical change required by the presentist. I take a modified process-based approach and propose a hierarchical ontological model based on four categories: ‘concrete substance’, ‘powerful properties’, ‘pure process’ and ‘interaction event’. The mutual dependency of pure process and interaction event reflects the equally primitive nature of persistence and real, metaphysical change. It also represents the wave-particle duality of concrete substance at the fundamental level. The compatibility of the proposed ontological model with a reductionist model of relativistic spacetime is argued for on the basis of a category alignment with Belkind’s (2012) Primitive Motion Relationalism. The latter provides the mechanism for B-series spacetime to emerge as the structure of a reality within which persistence and real, metaphysical change are primitive.

6.2 Requirements on a Suitable Ontological Model

The task of ontology is to establish a structured categorical scheme that best aligns with the truthmakers implied by both natural language and scientific discourse (e.g. Seibt, 2009, p.482). The starting point of such a task is to define or delimit the scope of that reality; the ontological scope here is the nature of concrete existence, or concrete being. The reality, or otherwise, of abstract entities (for example, universals) is excluded at the outset. Consequently, a suitable ontological model must be able to explain successfully the inferences drawn from our natural language statements about existence in time, or spacetime.

The arguments developed so far impose three requirements on a suitable ontological scheme.

> R1: The categories of the ontological schema should provide compatibility with our best physical theories
>
> R2: B-Series spacetime should reduce to the structure of reality
>
> R3: The ontological categories should reflect the metaphysically primitive nature of both real change and persistence; where real change and persistence are defined as follows:
>
>> Def_{RC}: Real change $=_{\text{def}}$ something coming into existence and/or something going out of existence
>>
>> Def_{PS}: Persistence $=_{\text{def}}$ continuity of existence

R1 reflects the overarching aim of the thesis which is to establish an ontology for Existence Presentism compatible with physical theory. R2 accommodates the arguments of Chapter 2 that a reductionist approach to spacetime provides the presentist with a route to achieving such compatibility. R3 embodies the conclusion of Chapter 5.

I begin by drawing an analogy between persistence and real change, on the one hand, and the continuant-occurrent distinction, on the other. I note the difficulties in combining such opposing entities within a unified ontology, and then consider the potential of the category of process to achieve a duality between continuant and occurrent.

6.3 The Occurrent-Continuant Distinction

It is noted in § 5.9.1 that, as formulated, persistence and real, metaphysical change are opposing aspects of reality. Persistence seen as the continuation of existence is orthogonal to a coming into or going out of existence (real change). This contrary nature is to some extent reflected in, what Simons (2000, p.78) refers to as, the 'puzzling duality at the heart of our conception of the world which calls out for metaphysical clarification'. The duality he refers to is that between two categories of particular: continuants and occurrents.

The terms 'continuant' and 'occurrent' originate from W.E. Johnson (1921 and 1924, quoted in Simons, 2000, p. 78) and the category division implied aligns with the distinction between endurance and perdurance. Johnson defines a continuant as:

> that which continues to exist throughout some limited or unlimited period of time, during which its inner states or its outer connections with other continuants may be altering or may be continuing unaltered […] Now while we cannot say that a continuant occurs, we *can* say that a *state* occurs; and anything that may be said to occur will be called an 'occurrent'. (1924, pp. xx-xxi, quoted in Stout, 2016, p. 41)

To the extent that continuants continue in existence (in their entirety) over time they exemplify persistence, defined as continuing existence (Def_{PS}). This would seem to suggest that continuants, in some guise, should figure as a category in the proposed ontology.

Occurrents, on the other hand, *happen* or *occur*, at given times or intervals of time, and so are intrinsically temporally bounded. Unlike continuants they possess temporal parts[124] or successive stages and persist by perduring (e.g. Simons, 2000). Events are archetypal occurrents: a flash of light occurs at a given time, whereas a conference can take place over two days. Events are also intimately connected with change (e.g. Davidson, 2001, Lowe, 2002) but events are not themselves *subjects* of change (unlike continuants), rather they *are* changes (Mellor, 1981, Simons, 1987, Galton and Mizoguchi, 2009). In their temporal extreme events are *instantaneous*, such as a flash of light or the Big Bang, and as such represent points at which things come into or go out of

[124] Definitions of temporal parts vary, but essential to the notion is existence *at a particular time* e.g. 'parts which exist solely because of its existing at a certain time' (Simons, 2000, p. 78).

existence. This suggests the potential for a category aligned with occurrents to represent real change (Def_{RC}).

It might be countered that not all occurrents obviously involve creation or annihilation, for example, a collision, or a temporally extended event such as a battle. Although such examples are not so intuitive, a collision between two cars is the point at which dents, for example, are created on both vehicles. Similarly, at the sub-atomic level, proton-proton collisions involve the creation of pions and other particles. Even purely elastic collisions are points at which something new comes into existence, namely a reversal in the direction of motion of each participant. I would argue that this also applies to temporally extended events, such as the Battle of Hastings and a wedding ceremony. Temporally extended events consist of a collection of different phases or temporal parts. As occurrents they are also temporally bounded to the extent that, in the limit, there is a temporal part, or occurrence, that represents the point at which they begin (to exist) and the point at which they end (go out of existence).

If events are indeed changes and, in the temporal extreme, represent points of absolute creation and annihilation they exemplify real, metaphysical change. This indicates that occurrents, or events, should also feature as a category within a suitable ontology.

Both occurrents and continuants reflect important elements of our conceptual scheme of reality and if the suggestion, that they exemplify the opposing features of real change and persistence, is on track, requirement R3 demands an ontological framework within which these categories are equally metaphysically fundamental. This presents a significant challenge. The problem, as Aune (1986, p.115) notes is 'how such categorially different entities fit together in a single world'. Consequently, there has been a tendency in the philosophical tradition to reduce one to the other (Aune, 1986, p. 105 and Simons, 2000, p. 78). This is unsurprising given that, in exemplifying persistence and real change (as defined in § 6.2), they represent opposing aspects of reality.

There are persuasive arguments on both sides of the debate.[125] Those who follow in the Aristotelean tradition (such as Descartes, Leibniz, Kant and latterly, Strawson, 1959) see substance, or continuants, as ontologically fundamental, whereas occurrents (such as events, or processes) are derivative. On the other hand, the influence of modern physics has led others (such as Russell, 1927, Lewis, 1983 and Sider, 2001) to consider events as fundamental and regard substances as reducible to occurrents (e.g., by being a succession of temporal parts).

Nonetheless, the consideration of temporally extended events, in the example above, provides a hint of a possible resolution. Temporally extended events, such a battles and weddings, (as opposed to instantaneous events) can also be regarded as *processes*: an unfolding series of events, or stages. Although such processes comprise a series of changes (events) there is also a unity across a temporal interval which permits re-identification as the *same* process (e.g., a wedding, or a battle). To this extent processes exhibit continuity as well as change. At first glance this suggests the category of process has the potential to model a duality between continuants and occurrents, and so provide a means of internalising these two opposing aspects of reality.

6.4 Processes – a Duality of Continuant and Occurrent?

Some support for the potential of the category of process to represent the duality between occurrents and continuants can be seen in the work of Stout (2016) and Steward (2015).

[125] Strawson (1959, pp. 15-58) argues that the ability to re-identify particulars requires reference to something that continues in existence over time, in other words, continuants. Whereas, under Quine's (1948, p. 32) criterion of ontological commitment, the extensive use of singular noun phrases (e.g. 'the Battle of Hastings') provides *prima facie* support for the existence of events. In a similar vein, Davidson (2001) argues that events are required as a separate ontological category in order to account for the logical form of certain sentences involving adverbial expressions (*ibid.,* p.166), such as 'the sun shone brightly yesterday', since 'brightly' and 'yesterday' appear to describe an event: the sun's shining. Also, in the case of action sentences certain entailments are difficult to explain without positing the existence of events. 'Brutus stabbed Caesar in the back' (a three-place relation) entails that 'Brutus stabbed Caesar' (a two-place relation); yet the entailment is difficult to explain without accepting the existence of a certain event (the stabbing of Caesar by Brutus) which possesses the property of *being done to Caesar's back* (*ibid.*, p. 136). Such examples also portray the explanatory role that occurrents play in accounting for change and causal relations.

Stout (2016) argues the case for a unified category of 'occurrent continuants' and considers that certain processes are paradigm examples of this category. These include processes such as 'the process of my living my life' and 'the pen falling off the table'. Specifically, these are occurrences that 'are, were, or will be happening' (2016, p. 50) and where reference to them involves using the verb with a progressive aspect. He argues that such happenings (which are therefore *occurrents*) are also continuants, on the basis that continuants are best characterised as 'things that primarily have their properties at a time' (*Ibid.*, p. 44), rather than atemporally. According to Stout, the fight that was happening on his street the previous night (an occurrence) is something that continues for a period of time and possesses different properties at different times: 'at first it was quite brutal, but after a few minutes it became less ferocious' (*Ibid.*, p.50).

Occurrent continuants can also be causal, for example, the currently happening destruction of the rainforest is causing an increase in global warming. For this reason, Stout argues, they must be a part of the fabric of objective reality, rather than merely linguistic peculiarities.

Steward (2015, p. 120) objects that the type of processes Stout refers to do not primarily have their properties *at* times, rather they are properties that apply *between* times. The continuous dripping of a tap may become irregular, but the irregularity of its dripping is a description applicable only over an interval of time, rather than being a property had at a given time which is characteristic of continuants (for example, being 'blue at t2'). Nonetheless, the fact that properties apply only between times does not mean that they are held atemporally, as is the case for occurrents. Steward concludes that processes are therefore a unique species of entity that fall *between* the occurrent-continuant divide and share some of the characteristics of each.

Irrespective of whether processes can truly count as both occurrents and continuants, as Stout maintains, or whether they represent a unique category between occurrents and continuants, they do appear to exemplify both a continuity of existence and various points at which something comes into, or goes out of, existence. In the following I assess the extent to which the category of process is able to perform this dual ontological role, with reference to the process ontologies of both Rescher (1996) and Seibt (1997). A more detailed analysis of the accounts reveals that a single category ontology, despite its original promise, is unable to reflect these opposing features of reality.

6.5 Process Ontology

Process ontology ostensibly claims a unification of both continuity and real change (e.g. Rescher, 1996, Salmon, 1994) and processes are considered to internalise both these temporal aspects of reality. Underpinning this claim is the close connection between processes and events that is assumed under process-ontological models, and this has been alluded to above. Processes are temporally extended (i.e., they are never instantaneous), and to this extent they exhibit continuity, or an ongoingness, such as the smoothing of a pebble. They also involve change, and to this extent encompass more or less instantaneous events. At the microscopic level the smoothing of the pebble involves changes, such as the detachment of microscopic particles.

6.5.1 Rescher's Approach

Rescher (1996) provides a systematic process metaphysics, within the arena of analytical philosophy, which seeks to avoid the atomism of Whitehead's process ontology. For Rescher, processes are continuous entities rather than constituted by the discrete 'actual occasions' of Whiteheadian process ontology. Rescher defines a process as:

> a coordinated group of changes in the complexion of reality, an organised family of occurrences that are systematically linked to one another either causally or functionally […] A process consists in an integrated series of connected developments unfolding in conjoint coordination in line with a definite program. (p.38)

For Rescher, processes persist by maintaining self-identity through the functional unity (the 'unity of a lawful order', p.39) that connects the occurrences that comprise the process. For example, the acorn and the fully grown oak tree are connected by the functional unity represented in their genetic coding.

Processes also exemplify change in the sense that they incorporate changes and, in doing so, display an ‘internal complexity’ (p.39):

> A process does not change as such – as the particular overall process at issue – but any such process can incorporate change through its unifying amalgamation of stages or phases (which may themselves be processes). Even as a story can encompass foolishness without itself being foolish, so a process can encompass changes without itself changing. (p.39)

This ostensive unification of continuity and change within the category of process is, however, illusory. It fails because a single-category ontology is unable to model what are opposing features of reality. The problem is this. The entities referred to as changes (which are also variously labelled as events, occurrences or developments by Rescher) must also *themselves* be processes - there is no other category within the ontology. As processes, they do not themselves change: as Rescher emphasises, their defining feature is continuity in the form of a functional unity. Rather changes, as processes, encompass further changes, but these further changes are *also* processes (whose defining feature is continuity) that do not themselves change. This analysis proceeds *ad infinitum*. Processes encompass changes, but these changes are merely a matter of ‘internal complexity’: in other words, they differ in their functional characteristics. The issue here is not that there is a problem with an infinite layer of processes[126] but, rather, that there is *nothing more* to change than functional variation. As such this is not sufficient to support the real, metaphysical change that is indicative of temporal, rather than spatial, variation. Rescher himself alludes to precisely this point:

[126] For example, Tahko (2018) argues against the necessity for a mereological ‘bottom level’ to reality and instead understands the fundamentality of reality in terms of ‘ontologically minimal elements’. This allows for monism (*a la* Shaffer’s priority monism) under which the universe as a whole is the fundamental element. It can also allow for metaphysical infinitism, of the sort encountered in structuralism, where a structural element (for example, fractal structures) may be infinitely repeated.

> just as the static complexity of a set of (filmstrip-like) photographs of a flying arrow does not adequately capture its dynamic nature, so the conjunctive complexity of a process's description does not adequately capture its transtemporal dynamics. (p. 38-39)

In appearing to address this, he proceeds to suggest that the 'programmatic nature' of the functional signature of a process (i.e., the fact that the different stages are causally or lawfully connected) ensures spatiotemporal continuity: 'it is of the very essence of an ongoing process that it combines existence in the present with tentacles reaching into the past and the future' (p. 39). However, this merely reinforces the continuity, or *persistence*, of processes rather than indicating how processes incorporate real change that is over and above functional variation.

The problem is in essence this. If process is the sole category in the ontology, then the whole of what exists is process, and if a process cannot itself change then it follows that the whole of what exists cannot change. This is contrary to the thesis of metaphysical change (§ 5.3.2) and indicates that, as defined within Rescher's account, the category of process does not reflect the metaphysically primitive nature of real change (R3). Given that real change (Def_{RC}) and persistence (Def_{PS}) represent opposing features of reality, this is not that surprising; indeed, it is hard to see how they *could* be reflected within one and the same ontological category.

It is clear that Rescher does see the category of process as sufficient to exemplify both persistence and change. Elsewhere he states that 'processes effect changes. They make a difference in the world's scheme of things in actualising a heretofore open, indeterminate future in ways that distinguish it from the determinate past' (1996, p.85). In describing processes in this way Rescher implies that changes are connected with 'actualising', or a bringing into existence, and this *is* in alignment with the definition of real (metaphysical) change (Def_{RC}). Nonetheless, the entities that Rescher recognises as connected with change – namely events, occurrences and developments - do not belong to any ontological category separate from that of process,[127] and this, as suggested above, makes it impossible to represent *both* real change and persistence as metaphysically primitive.

6.5.2 Seibt's General Process Theory

Seibt's (1997) General Process Theory is an axiomatic, process-ontological framework that aims to align with the methodological commitments of analytical philosophy. Seibt, like Rescher, subscribes to a one-category ontology based on what she terms 'general processes'. General processes are 'concrete, dynamic, non-particular individuals' (2009, p. 479) individuated by a 'specificity in functioning'. In assessing the extent to which the category of 'general process' might offer scope for accommodating both real change and persistence, I refer in what follows to Seibt's account of persistence (2007) and her account of emergence (2009).

For Seibt (2007), the difference between change and persistence is reflected in the different extent to which general processes are like-parted (homomerity) and self-parted (automerity). These features define their mereological signature. Homomerity is the extent to which the spatiotemporal parts of an entity of kind *K* are themselves of kind *K*. As such, homomerity is common to masses or stuffs, for example, sand and water. In contrast, automerity represents the degree to which the whole of an entity, *S*, in a functional sense, is included in any of its spatiotemporal parts. 'Activities' such as raining and snowing possess maximal automerity: their functional activity recurs throughout any spatiotemporal region in which they occur, and throughout *any part* of that spatiotemporal region.

This distinction allows Seibt to differentiate between processes that are 'developments', and those that are 'activities'. Developments are minimally temporally automerous and event-type processes, such as explosions. They manifest an internal temporal differentiation by comprising a sequence of different dynamical aspects; as such they are the truth-makers for statements

[127] For example, Rescher states that any event 'dissolves into a manifold of processes' (1996, p. 29).

about change. Conversely, activities are relatively generic (though concrete) general processes (such as snowing or raining) that are maximally temporally automerous, and so are characterised by a continuous recurrence of some functionally specified dynamic. They are exemplars of persistence and provide the truth-makers for statements concerning persistence.

In so far as changes are indicated by a sequence of different dynamical aspects Seibt's account appears, *prima facie*, similar to that of Rescher. Nonetheless, Seibt's account is more nuanced and she reconciles change and persistence, within one and the same entity, by taking advantage of a flexibility associated with a non-transitive mereology. The account, though complex, deserves further analysis to assess how successfully the category of general process accommodates both real change and persistence.

Seibt's non-transitive mereology employs the 'is part of' relation to denote a relation of functionally 'belonging with', with no implication of spatiotemporal containment. This permits the functional whole, α, (a complex dynamic) to contribute functionally to its own parts. For example, pancreatic enzymes are part of the correct functioning of the pancreas, this in turn is a functional part of the digestive system, which in turn is part of the day to day functioning of the whole individual, α. That individual might, however, take the drug Creon and in doing so is able to contribute to the correct functioning of their pancreatic enzymes. The mereological relations between the different dynamics constituting the complex whole, α, are specified in terms of functional 'partition levels'; these become more and more fine-grained and specific the lower down the hierarchy. The action of specific pancreatic enzymes is an example of dynamics at such a lower partition level.

This model of individuals, as hierarchical complexes of dynamics, provides an account of how statements about both persistence and change may apply to one and the same entity. Given the Statue of Liberty, statements about its persistence denote the relatively coarse-grained, complex dynamics at the pinnacle of the partition level. A statement of identity, or comparison of sameness, is 'mereologically shallow' and masks the fact that it is constituted by many different partition levels of dynamics some of which exemplify change, such as those lower down the (functional) hierarchy. The difference between change and persistence is therefore a matter of perspective or level of granularity.

> In short, statements about persistence and change involve different calibrations of the 'lens of specificity' that guides our comparisons of functionally individuated individuals: persistence statements express the transtemporal identity of *more generic* individuals (dynamics), statements about change express the difference between *more specific* individuals (dynamics). (Seibt, 2007, p. 160-161)

Seibt's non-transitive mereology certainly succeeds in ameliorating the problem of temporary intrinsics, since the persisting entity, α, (for example, the Statue of Liberty) can be part of the interaction dynamics involved in change, or alteration, without contradiction. The account thereby maintains the intuitive appeal of endurantism, in that it is the whole entity that participates in change. Nonetheless, the approach fails to circumvent the criticism directed at Rescher's account. Change is still simply functional variation ('a difference between […] (dynamics)'), and something that is a matter of perspective: 'A more "fine-grained" comparison will reach into "deeper" partition levels and reveal difference' (p.160). Change is neither metaphysically primitive nor intrinsic to the category of general process.

Change, as functional variation, also fails to reflect the real, metaphysical change that is sought. Real, metaphysical change ($\mathrm{Def}_{\mathrm{RC}}$) involves absolute creation and/or annihilation and it is only *this* rendition of change that can meet the requirements of a presentist account (Chapter 5).

In contrast, Seibt *does* seem to regard continuous recurrence (i.e. persistence) as a defining, or intrinsic, feature of general process (2007, pp. 148-155), rather than, as in the case of change, simply a matter of perspective on the mereological hierarchy. Indeed, Seibt states that the model for the category of general process is 'subjectless activities' (p. 147), such as snowing, and her description of them suggests that they exemplify a primitive persistence, in the form of an inherent recurrence.

Subjectless activities are 'dynamic but they are not changes […] activities do not involve internal temporal difference' (2007, p.148). Further, a subjectless activity is both like-parted and self-parted (p.152-153) and in this sense 'can contain itself as part of a part' (p.155). Such self-containment means that activities exist 'continuously throughout the period at which they exist. Temporal continuity is the literal ubiquitous recurrence of one and the same feature, down to the smallest conceivable regions or "points in time"' (p.155). This emphasis on persistence in defining the category of general process means that, as was seen with endurance (§ 5.4.2), real change is compromised by a commitment to the priority of persistence.

Process theorists clearly wish to see change as internal or intrinsic to processes. The recognition that change needs to be internalised, in order to reflect adequately an objectively dynamic reality, is well-motivated but the mechanism fails. For both Rescher and Seibt, processes incorporate change, by way of successive stages or elements that exhibit dynamic variation, but in doing so change appears merely as (functional) variation rather than as real, metaphysical change.

6.5.3 The Relevance of Interaction

Despite the fact that change under Seibt's account does not represent the real, metaphysical change required by the ontology sought here, her account of emergence (Seibt, 2009) does provide an important insight into a potential mechanism to achieve a duality between change and persistence, at an ontological level. This mechanism is the *interaction* of processes.

In showing how her process ontology has the tools to account for different types of emergence, Seibt proposes a distinction between combinations of general processes that involve interactions, and those that are 'mere collections' or ‘sums’ of processes.[128] Where processes *interact* they ‘interfere’ and a new ‘complex dynamics’ results (2009, pp. 492-493). She provides an example of two processes, the boiling of water, α, and a window pane, β, that interfere in some spatiotemporal interval, γ.[129] This produces an ‘interference product’, condensation (η), which is a new complex dynamics, or general process; it is new in the sense that it ‘does not occur anywhere in the partition of α nor of β’ (p. 493), the component processes. Seibt illustrates this in the diagram shown below (Seibt, 2009, p. 493, Fig. 3).

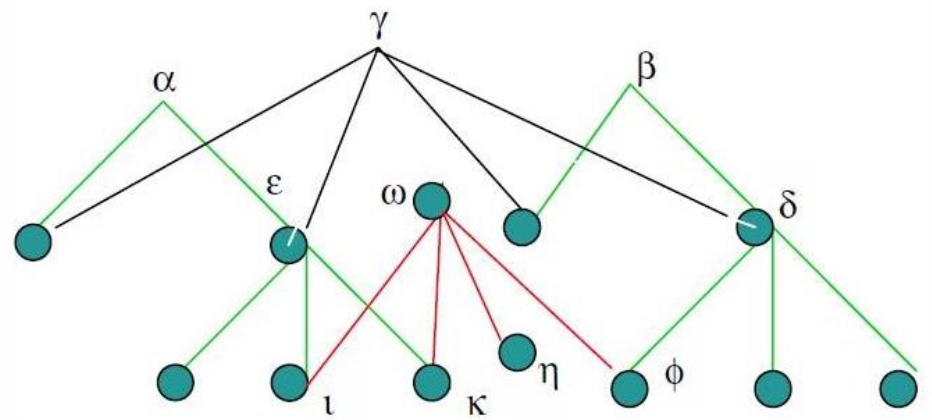


Fig. 3 Example of an interference structure; the interference focus ω is the sum of some 2-parts of α and some 2-parts of β, as well as the interference product η. For illustration, let r be a variable for some spatiotemporal interval γ, and assign to the constants of the partition the following (generic) processes. Let α: boiling of water in γ, β: being a window pane in r, ε: the evaporating of water in r, δ: being glass at temperature T in r, ϕ: being a smooth surface at temperature T in r, ι: separation of bonds among water molecules in r, κ: air movement in r; η: condensation in r.

This description reveals that, under Seibt’s account, the interaction of general processes is associated with the production of a new process, in this case, condensation. Although this is not how change is formulated within Seibt’s ontology, this illustration of novel production *is* consistent with the proposed formulation of metaphysical change (Def_{RC}) and provides the potential to secure it within a modified process ontology.

Consistent with Seibt’s single category ontology, interaction is itself regarded as a process (‘interaction dynamics’) and is not metaphysically primitive. Interaction requires that the participating processes, *x* and *y,* overlap

[128] A ‘collection’ or ‘sum’ of processes would occur, for example, where 50ml of water is added to a jug containing 500ml of water.
[129] Spacetime, for Seibt, is also a general process.

spatiotemporally, and Seibt's definition accords with our intuitive notion of interaction as requiring spatiotemporal coincidence. She defines interaction,[130] for some spatiotemporal region, *r*, (p.497) as follows:

> (D6: Sequential interaction): An interference of *x* and *y* is a sequential interaction if *x* and *y* spatiotemporally overlap in *r*, and the interference focus $[z]_r$ has the temporal homomerity and automerity profile of a series of developments, and there are at least two interference products that do not exactly overlap temporally (i.e., are not co-occurrent).

For Seibt, spacetime is also a general process, referred to as *R*, and it has a locating function for all concrete general processes. A specific occurrence of a general process, α, (for example, snowing) is spatiotemporally located by its 'interference' with *R* (the spacetime dynamic), and this provides for the specific occurrence of, for example, snowing in the Alps in February. This interference occurs as an 'interference focus' (which defines the spacetime location), and is given mereologically by a sum of n-parts of α and *R*. In order for two general processes to overlap spatiotemporally (and so interact) they must therefore participate in the same 'interference focus'.[131]

Formulating real change in terms of the *interaction* of processes therefore provides scope for a process ontology to represent real change as something ontologically distinct from persistence. It also aligns with the discussions in Chapter 5 (§ 5.7.3): in arriving at an appropriate formulation of real change it was discussed that qualitative change, as it is in reality, does appear to involve some prior causal *interaction* in addition to a gain or loss of properties. However, the role accorded to spacetime dynamics (*R*) under Seibt's account

[130] Seibt draws a distinction between two types of interaction: sequential and co-occurrent. For simplicity, only one definition is provided here. However, both definitions include spatiotemporal overlap.

[131] As I read Seibt, novel production requires the '*interaction*' of processes rather than merely their '*interference*'. Interaction requires spatiotemporal overlap (as defined in 2009, pp. 497-498); it results in the mutual change of the interacting dynamics and is essentially causal. In contrast, an interference (p.493) is a 'mereological structure' and the resultant 'interference product' is not a novel creation, though it is a different complex dynamic. Thus, spatiotemporal location is an 'interference' (rather than an 'interaction') between a general process, α, (for example, snowing) and the spacetime dynamic, *R*, and the resultant interference product is a spatiotemporally bounded 'amount of α'. As such, it is a different dynamic entity from α, though they share 'parts', functionally construed.

presents a problem. As Seibt admits: 'the GPT-account of location combines most straightforwardly with an entitative (commonly called "substantivalist") conception of spacetime' (*Ibid*., footnote, p.494). If a process account requires a substantival notion of time to model real, metaphysical change this is contrary to the model of presentism being pursued (requirement R2).

An alternative option is to utilise a relational model of spacetime. However, it is not now clear how interaction could be defined in the absence of substantival time. Under a relational theory of time, spatiotemporal relations supervene on, or are derivative of, the relations instantiated by material entities (in this case general processes). For example, spacetime could be seen as consisting in an abstract ordering of concrete processes that, through their mutual interaction, constitute the causal nexus of reality. In this case, though, spatiotemporal coincidence would need to be grounded in some relation between processes themselves, and the most obvious candidate for this is the overlap, or intersection, of those processes, or, in other words, an 'interaction'. It would appear then that under a relationist account the concept of interaction (between processes) would have to be primitive.

In conclusion, as formulated under the process ontologies considered, the category of process is able to reflect the primitive nature of persistence through the category feature of functional recurrence. The interaction of processes, and its association with the production of new processes, also suggests the potential to incorporate real, metaphysical change. However, the requirement for the ontology under development to facilitate a reductionist model of spacetime (requirement R2) suggests that interaction must be primitive.

I intimated earlier that a single-category process ontology is insufficient to capture the primitive nature of real, metaphysical change. Yet if the interaction of processes is primitive, and if interaction does provide for real change (construed as absolute creation or annihilation) this appears to suggest that a purely process ontology *is*, after all, able to provide what is needed under the account. However, in what follows I argue that there is good reason to regard the interaction of processes as a distinct ontological category.

6.6 Interaction – the Case for a Separate Category

I make the argument that interaction is a separate, ontological category from that of process, and one that aligns with the essential features of occurrents (or events). The resulting ontological framework meets the original aim of reflecting the primitive nature of both real change and persistence, and will be seen to have several benefits. The most significant advantage is that it provides an ontology conducive to a compatibilist account of presentism, one that regards spacetime as derivative of an objectively dynamic reality.

For Seibt, interaction is subsumed under the category of 'general process' (as 'interaction dynamics') which has, as its model, subjectless activities such as snowing, raining and oscillating. As such the category of process exemplifies persistence (as continuing existence) in the form of the continuity or recurrence of some functionally-specified activity. To this extent activities, as 'pure' processes, are archetypal continuants.[132] They range from the more dynamic processes, such as the swinging of a pendulum, or the motion of a brick through the air, to what Simons (2000, p. 70) describes as 'boring continuants', such as rocks and windows. Rocks and windows, in so far as they 'continue to exist by sheer inertia' (*Ibid.*) are also pure processes to the extent to which they continue on, as they are. Whether dynamic or boring, each is characterised by some functional recurrence, and it is to this extent that pure processes continue in existence. However, there is good reason to regard the interaction of processes as a separate ontological category, and this is because interactions possess neither of the two essential category features of processes.

First, interactions are not a continual recurrence of some functional dynamic. An interaction is an overlap, or coincidence, of processes which by its very nature is a one-off, it is not something that recurs. This is not to say that two processes cannot repeatedly interact, but in that case the interactions would be distinct entities, each occupying a defined point, rather than a recurrence of the

[132] Galton and Mizoguchi (2009) concur with the view of processes as continuants (the *whole* process happens at each moment at which it is occurring), though it is accepted that a commonly accepted view is to regard processes as a series of stages and so derivative of events, or occurrents. I address this potential criticism in § 6.8.

same interaction. The discrete nature of interactions suggests an ontological profile more akin to that of occurrents, or happenings, rather than continuants.

Second, interactions do not exemplify persistence, as continuing existence. Interactions are points at which something comes into existence, or goes out of existence, and it is to this extent they exemplify real, metaphysical change (Def_{RC}). When processes interact they lead to the creation of something new (a new process) or the destruction of something existing. When the flying brick interacts with the window something novel is created (shards of glass which fall to the floor, pieces of broken brick which fly off at an angle) and something ceases to exist (the fully functioning window, the forward motion of the brick). An interaction, as the *point* at which something comes into existence (or goes out of existence) has an ontological profile that is discrete and point-like, and for this reason it cannot also exemplify *continuing* existence. Continuing existence, by its very nature, has a completely contrary ontological profile, one characterised by extension i.e., ‘extending on’. The difference in ontological profile between process and an interaction (of processes) is analogous to the difference between two-dimensional and one-dimensional entities. It is in this sense that real change and persistence are opposing, or orthogonal, features of reality – they have contrary, or opposing, ontological profiles. If interactions exemplify real, metaphysical change then they cannot *also* exemplify persistence (as defined). For the two reasons outlined above the interactions of processes (as exemplars of real change) must be considered as a separate category within the proposed ontology.

As points of creation or annihilation, interactions of processes align with the category of occurrents, for which events are the paradigm. Accounts of the properties and extension of the concept ‘event’ vary between commentators[133] but in general the defining feature of events is that they occur or happen. They are also associated with a definite, or well-defined spatiotemporal location (and so are datable, or locatable). Events are associated with changes and in their

[133] A comprehensive overview of the different accounts of events is provided in Casati and Varzi (2020).

temporal extreme (e.g. a flash of light) events are instantaneous points at which things come into or go out of existence.

The arguments above indicate that at least two ontological categories are required in order to reflect the metaphysically primitive nature of real change (defined in terms of absolute creation and annihilation) and persistence (as continuing existence). These two categories characterize each of the objective correlates of tense, they also mirror the occurrent-continuant distinction. The category of process, suitably defined, provides scope for modelling persistence whereas the interaction of processes, formulated as a separate ontological category, is able to reflect real change. This ontological framework is developed in the following section.

6.7 The Proposed Ontological Model

In what follows, I define the two categories required to model the objective correlates of tense. I refer to these as ‘pure process’ and ‘interaction event’ to distinguish these ontological categories from the terms ‘process’ and ‘event’, as used in ordinary language. In § 6.8 I describe how the ontological categories described account for the inter-connection of the terms ‘process’ and ‘event’ in ordinary discourse.

> **Def$_{\mathbf{PP}}$:** *x* is a *pure process* $=_{\text{def}}$ *x* exemplifies a continuity, repetition or on-goingness, of some functionally specified activity.
>
> **Def$_{\mathbf{IE}}$:** *x* is an *interaction event* $=_{\text{def}}$ *x* is an interaction between two or more pure processes and is a point of novel creation and/or annihilation of pure processes.

In defining the category of *pure process* I part company with the process ontologies of Rescher and Seibt; this is required in order to establish the ontological distinction between persistence and real change. For both Rescher and Seibt although the defining feature of the category of process is continuity, in the form of a functional unity, processes encompass change by manifesting an internal functional differentiation or complexity; change is thereby merely functional variation and not real, metaphysical change (§ 6.5).

The category of pure process is *not* characterised by internal functional differentiation. The category includes, as its models, those processes that Seibt would describe as subjectless activities, processes that are maximally temporally automerous, such as snowing and raining. It also includes physical processes such as oscillating, vibrating and inertial motion. On a fundamental level pure processes exhibit a continuity of existence and thereby reflect the metaphysically primitive nature of persistence. As such pure processes are continuants.

As argued above, the interaction of pure processes has to be primitive in order for the ontology to be compatible with a reductionist theory of spacetime. The category of *interaction event*, as the point at which pure processes come into or go out of existence, reflects the primitive nature of real, metaphysical change. The model for interaction events are instantaneous events that occur or happen, such as a flash of light or the Big Bang; interaction events are therefore archetypal occurrents.

As defined the two categories are mutually interdependent and equally primitive. Interaction events depend upon the interaction of pure processes and pure processes depend upon interaction events to come into existence. Connecting the categories in this way resolves Simons' (2000) 'puzzling duality' between continuants and occurrents; it also provides a means of reconciling the two opposing aspects of reality represented by persistence and real change. This has intuitive appeal. An ontological scheme which regards both continuants and occurrents as equally primitive and mutually dependent explains why we require both in our conceptual scheme of reality, and why the arguments on both sides of the debate are persuasive. The analysis of causal statements suggests that events, as occurrents, are required as causal relata (Davidson, 2001, p. 166). The logical form of certain sentences also supports a *prima facie* ontological commitment to events (Davidson, 2001, p. 136).[134] On the other hand, continuants (such as objects and substances) provide a constant

[134] The example Davidson provides is that the statement 'Brutus stabbed Caesar in the back' (a three-place relation) entails that 'Brutus stabbed Caesar' (a two-place relation); yet this entailment is difficult to explain unless we accept the existence of a certain event (the stabbing of Caesar by Brutus) with an associated property of *being done to Caesar's back*.

frame of reference sufficient to ground the re-identification of particulars over time (Strawson, 1959). It also seems difficult to conceive of insubstantial events, to this extent events seem to require continuants; complex events (such as a wedding) appear to presuppose persisting objects which participate in them and which continue to exist before and after the event. The category of continuant is also needed to account for those 'boring' continuants, mentioned previously, that exemplify no change.

There are three outstanding issues to resolve and these will be addressed in the remainder of this chapter:

1. Further clarification is needed as to how the proposed ontological model aligns with the use of the terms 'process' and 'event' in ordinary discourse; in particular, how the term 'event' covers both instantaneous and temporally extended occurrences.

2. The mutual dependency between the categories of pure process and interaction event, as defined, gives rise to the potential for a vicious circularity and infinite regress.

3. There is a need to demonstrate how the proposed ontological scheme gives rise to (B-series) spacetime as the structure of reality (requirement R2). This is necessary to show that the proposed presentist model is compatible with physical theory (requirement R1).

The first issue will be considered in the following section (§ 6.7.1) which considers an additional feature of events, boundedness. This serves to characterise better the difference between process and event, as employed in normal parlance, whilst reconciling linguistic usage with the underlying ontological reality. The notion of boundedness also provides the route to understanding how spacetime arises from a reality structured by categories that reflect the primitive nature of persistence and metaphysical change (issue 3). This will be examined in § 6.8.1 where an argument is made for an alignment between the proposed ontological scheme and Belkind's (2012) Primitive Motion Relationalism. The threat raised by the second issue will be ameliorated when the full ontological hierarchy is set out in § 6.7.3.

6.7.1 The Role of Boundedness in Connecting Processes and Events

An intimate connection between processes and events is reflected in ordinary language use and this is related to the intrinsically temporal nature of both. A process such as photosynthesis involves what are described as events - such as the interaction that occurs between a photon of light and a molecule of chlorophyll. Equally, temporally extended events, such as a wedding, include processes, for example, the procession of the bride down the aisle and the signing of the register. This intrinsic connection might explain the fact that, as Galton and Mizoguchi (2009, p. 79) note, 'the literature displays a strong tendency to gloss over the distinction between processes and events'.

For process theorists (e.g. Salmon, 1984) the distinction between process and event is normally given in terms of temporal duration. Events, such as an explosion, are relatively localised and of shorter duration than processes. In the limit, events are instantaneous and so can be seen as processes of minimal temporal extent. A similar characterisation is made by Seibt (2007), for her events are (general) processes with a distinct mereological signature, namely minimal temporal automerity. However, a distinction on the basis of temporal duration does not accommodate the fact that, in normal language use, events can also be temporally extended. In virtue of being so, they can encompass sequences of smaller events *and* processes.

In the following I introduce the concept of 'boundedness' to explicate further the category difference between pure process and interaction event and, in doing so, understand how the term 'event' is used to cover both instantaneous and temporally extended occurrences. I borrow the term 'boundedness' from Galton and Mizoguchi (2009, p. 75), though I employ it in a different way. They suggest that, in addition to a distinction in terms of temporal duration, the difference between process and event can be given in terms of discreteness, in a manner aligned with the count-mass distinction. Events are discrete and can be referred to using count nouns (e.g., one explosion) whereas processes are non-discrete and referred to using mass nouns (e.g., water, running).

In line with this distinction, Galton and Mizoguchi regard events as characterised by 'boundedness', and they emphasise that boundedness is to be carefully distinguished from having short temporal duration:

> […] boundedness is a precondition for the assignment of any definite duration: processes endure, but only once we have assigned bounds to them can we speak of duration, and the act of assigning bounds means that we have switched our attention from the process to an event. (2009, p. 75)

It is important to note that, as with other process theorists, switching between 'process' and 'event' is a matter of granularity for Galton and Mizoguchi, related to the level of conceptualisation of a given event or process. There is no implication of an ontological distinction.

Nonetheless, the concept of boundedness is a useful one which I will employ to indicate an ontological distinction between the categories of pure process and interaction event. As I use it, boundedness is an existential, rather than a temporal, notion. Interaction events are (existentially) bounded to the extent that they represent points at which things come into existence and/or go out of existence. Conversely, pure processes (construed as the continuity of some functionally-specified activity, for example, harmonic motion) are unbounded, to the extent that they continue on in existence or recur.

Concrete events, particulars to which we assign the term 'events' in normal discourse, all involve (at the ontological level) the occurrence of interaction events. This applies to both instantaneous and temporally extended events. Nonetheless, there is an ontologically significant difference between them. In the extreme, an instantaneous event, such as a collision or flash of light, involves a *single* interaction event, or one point at which something is brought into, or goes out of, existence. Instantaneous events can therefore be described as asymmetrically existentially bounded and it is in virtue of this that, in the limit, they have no duration. In contrast, a temporally extended event, such as World War I, to which we assign a definite temporal interval, consists of *two* interaction events (at the ontological level) and these define the beginning and the end of the temporal interval. Temporally extended events can be described as symmetrically bounded and, as such, possess a duration. The interaction event that defined the start of WWI was the assassination of Archduke Franz Ferdinand of Austria on 28 June, 1914; the interaction event that ended the war was the signing of the armistice agreement on 11 November, 1918. Events, regardless of their temporal extent, are ontologically distinguished from processes in so far as they consist of one or more interaction events (defined as points of existential creation and/or annihilation). This accounts for why, in normal language usage, the term 'event' can refer both to instantaneous and temporally extended particulars.

In everyday language there are occasions where the descriptors 'process' and 'event' are applied to one and the same particular, depending upon the conceptual focus of the assertion. This can also be explained in terms of the underlying ontology using the categories described. For example, the Battle of Hastings is described as a 'process' to signpost those features of it that exemplify a functional continuity, or recurrence – features that represent pure processes, ontologically speaking. It is a 'process' in so far as each spatiotemporal part of it (to a certain level of granularity) exhibits fighting. It can also be described as an 'event' to the extent that we wish to assign a definite temporal interval over which it took place. In assigning it a temporal interval, the beginning and end of that interval will consist (at the ontological level) of interaction events. It will later be seen that the boundedness of interaction events provides for the objective spatiotemporal intervals between events in Minkowski spacetime; the argument for this will be given in § 6.8.2.

In the following section I explain how the two mutually dependent categories of pure process and interaction event account for complex, everyday particulars. I then address the issue (issue 2, § 6.7) that a potential vicious circularity arises from the proposed ontological framework, by introducing a third category into the ontology (§ 6.7.3).

6.7.2 Accounting for Complex Entities

In addition to explaining how the term ‘event’ in normal usage can indicate both instantaneous and temporally extended events, I also need to show how the proposed ontology accounts for complex, everyday, concrete particulars, whether these are described as objects, events or processes.

Complex entities both persist and change to varying degrees, and a dual category ontology, under which occurrents and continuants are equally primitive and mutually dependent, accounts for the apparently contradictory nature indicated by the problem of temporary intrinsics. It also accounts, as seen above, for the intimate connection between processes and events in normal language.

Everyday, macroscopic, concrete particulars are a hierarchical complex, involving an interplay of pure processes and interaction events. The life span of any concrete object begins with an interaction event and ends with an interaction event; however, describing a given life span is relative to any one of multiple levels of granularity that corresponds with our conceptual focus and linguistic practice. At one level we might consider the beginning of an apple’s life to be the interaction event that is the interaction between the sperm (present in pollen deposited on a flower) and an ovule in the flower’s ovary. On another level of conceptualisation, the apple’s life starts when cell division begins and the petals surrounding the nascent fruit have fallen, alternatively it could be considered to be the point at which the fully developed apple has fallen, or is picked, from the tree. Regardless of the level of our conceptual perspective, the point at which a defined temporal period begins and ends consists of some interaction event and in each case this is an interaction of pure processes and the point at which pure processes are either created or annihilated.

If we take the beginning of the apple’s life to correspond with fertilisation, the pure processes involved in the interaction event are the motion of the sperm (from the pollen, down the style, and into the ovary) and the continuing existence of the ovule. The motion of the sperm is a pure process since motion counts as a continuing, or recurrent, dynamic. The continuing existence of the ovule is a pure process as it exemplifies persistence (defined as continuing existence). The interaction event is the interaction of these two pure processes and is the point at which a new pure process is created, in this case, a fertilised seed which continues on in existence. The interaction event is also the point of annihilation of the two interacting pure processes – the motion of the sperm and the continuant ovule.

The life of the apple, between its creation and annihilation, is a pure process since it is the recurrence (or continuing existence) of a specific functional unity of biological processes common to apples and determined by its genetic code. At a finer level of complexity its life also consists of a series of defined stages each of which is bounded by interaction events. For example, cell division, cell expansion, starch accumulation, starch decline, ripening, and ultimately the decay of the flesh. The life of an apple may also be terminated by a more clear-cut interaction event; such as being crushed in a cider press.

Charlotte's park run on Monday morning is another example of a complex particular which consists of both pure processes and interaction events. Charlotte's running is a pure process as it involves an activity ('running') that is the repetition of a functionally defined dynamic. It is also temporally bounded and so can be described as an event, that took place between 9.00am and 9.30am, since it is bounded by interaction events. Charlotte's running comes into existence at an interaction event, such as her first step onto the pavement as she leaves, and it terminates at an interaction event - the slamming of her front door when she returns.

In the absence of a separate ontological category of interaction event, a purely process ontology struggles to account for how it is that concrete processes come into, and go out of, existence. Equally, in the absence of a separate category of pure process, a purely event-based ontology struggles to account for the continuing existence of particulars. This is supported by considering extreme examples of both continuants and occurrents. The ideal 'boring' continuant, a perfectly formed rock that continues on in existence without ever undergoing any change, cannot be adequately modelled under a purely event-based ontology. Even if it is conceded that, in reality, such a continuant requires a creation event to bring it into existence, it does not seem possible to account for its *continuing* existence as a series of happenings, or events. Similarly, at the other extreme, the possibility of subjectless events, such as a flash of light (Strawson, 1959, p. 46), shows that not all events require the existence of continuants (e.g., one that flashes). In this case, it is difficult to accommodate such archetypal occurrents, which simply come into and go out of existence, under a purely process ontology.

In conclusion, the mutual dependency between the two ontological categories, of pure process and interaction event, under the proposed model provides a better explanation of complex entities, and the fact that they can both persist and change. It also accounts for the intimate connection between processes and events that is reflected in ordinary discourse.

6.7.3 A Third Ontological Category – Concrete Substance

The mutual ontological dependency between the two categories of pure process and interaction event raises the spectre of a vicious circularity and a potential infinite regress, as noted in § 6.7. This is addressed by the introduction of a third ontological category - the category of concrete substance - that sits above the categories of pure process and interaction event in the proposed ontological hierarchy.

The need to posit an additional ontological category is not only indicated by the potential threat of circularity. In the absence of some underlying material substance it is difficult to conceive of either a pure process or an interaction event. In the case of a pure process, there has to be *something* that continues on or recurs. Motion, previously cited as a category model for pure process, has to be the motion of some *thing* or material entity. It is equally difficult to conceive of an insubstantial interaction event; even a subjectless instantaneous event, such as a flash, has to consist *of something*, such as a flash of light or photons. Aside from this argument, the requirement for an additional ontological category is also informed by Quantum Field Theory.

Quantum Field Theory (QFT) is established as the predominant conceptual framework for describing matter at the fundamental level as it represents the empirically successful unification of Quantum Mechanics with the Special Theory of Relativity. As such, it is the best theory to date of the underlying structure of the physical universe. However, the extent to which QFT indicates an underlying ontology has been the subject of much debate; the central issue is whether a wave or a particle ontology is the better supported.

Physical theories are divided into those that are mathematically described in terms of particles (such as Newtonian mechanics) and those modelled by fields using wave equations (such as electromagnetism). Particles are discrete entities whereas fields are continua. However, the quantum field of QFT can be arrived at using two different routes, either through the quantisation of classical fields (this supports a wave interpretation) or by the quantisation of classical mechanics (which supports the particle interpretation). Added to this is the empirically verified observation that quantum phenomena can exhibit *both* wave and particle aspects (so-called 'wave-particle duality'), depending upon the experimental set-up. Kuhlmann (2002, 2018) provides a comprehensive discussion of the arguments on both sides of the field versus particle debate, and their contrasting ontological implications.

The quantum nature of the quantum field ostensibly supports a particle interpretation to the extent that a particle is essentially discrete. The quanta of the quantum field are quantised (or discrete) excitations of the field and possess quantised units of energy and momentum. However, the indistinguishability of quantum particles means that they are not re-identifiable individuals (Redhead, 1982) and the non-locality[135] of quanta also counts against a particle interpretation; unlike a field a particle cannot be found in two separate spatial areas.

The debate over the ontology of quantum field theory highlights that the quantum field, as peculiarly quantum in nature, is not adequately characterised under either a classical particle or a classical field ontology, but it exhibits

[135] Non-locality is described in more detail in § 1.4.3.

aspects of both. Nonetheless, what may be concluded is that there is a substantial *something* at the fundamental level that is characterised by positive values of energy and momentum *even in* the absence of matter, irrespective of how we may describe it within the theory. This substantial something reflects the sum total of energy-momentum from which the concrete universe is constituted. As such, the existence of an underlying substantial something indicates the need to posit a third ontological category, that of concrete substance, on which to ground the categories of pure process and interaction event. This ontological hierarchy is illustrated in Figure 6.1.

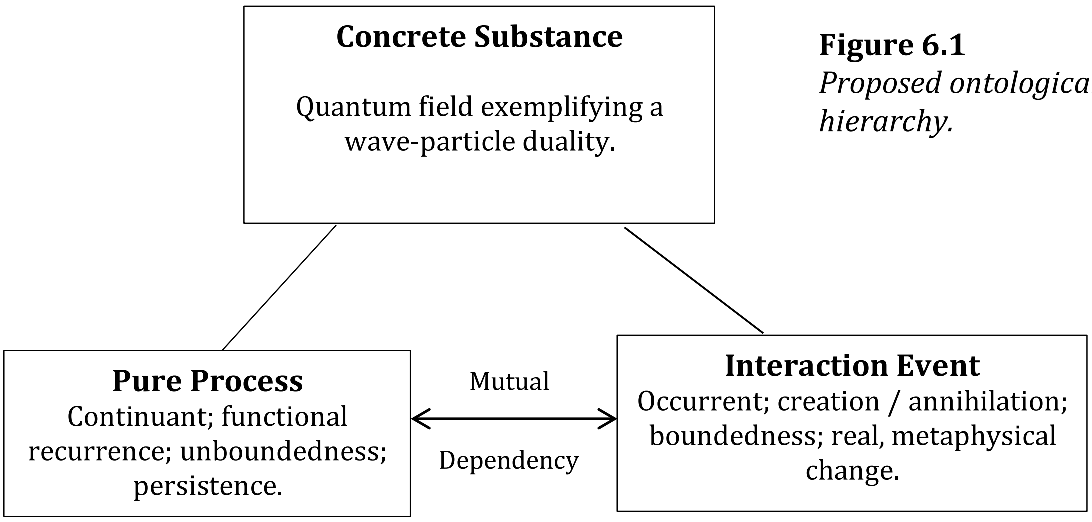


Figure 6.1
Proposed ontological hierarchy.

Positing a third ontological category of concrete substance addresses the issue (raised in § 6.7) that the mutual dependency between pure process and interaction event could generate a vicious circularity, and an infinite regress. The hierarchy proposed indicates that both pure process and interaction event are two categories, or modes, of an underlying concrete substance. At the fundamental level this substance exists as the quantum field which possesses energy-momentum and exhibits a wave–particle duality. The wave-particle duality of concrete substance is reflected in the mutual dependence, and equally primitive status, of the categories in the second tier of the ontological framework – pure process and interaction event. The wave-like aspects of the quantum field are modelled as fluctuations or excitations in energy density of an underlying continuum. In this manner the quantum field reflects the continuant nature of pure process and its characterisation in terms of a recurrent, functionally specified dynamic. The discrete, particle nature of the quantum field is revealed when there are *interactions* between quantum fields and these are associated with the creation and annihilation of particles at the fundamental level (Redhead, 1982, pp. 86-88). To this extent the quantum field is also occurrent in nature and aligns with the category of interaction event: as defined (§6.7), interaction events are (primitive) interactions between pure processes that result in novel creation and/or annihilation.

6.7.4 The Complete Ontological Model

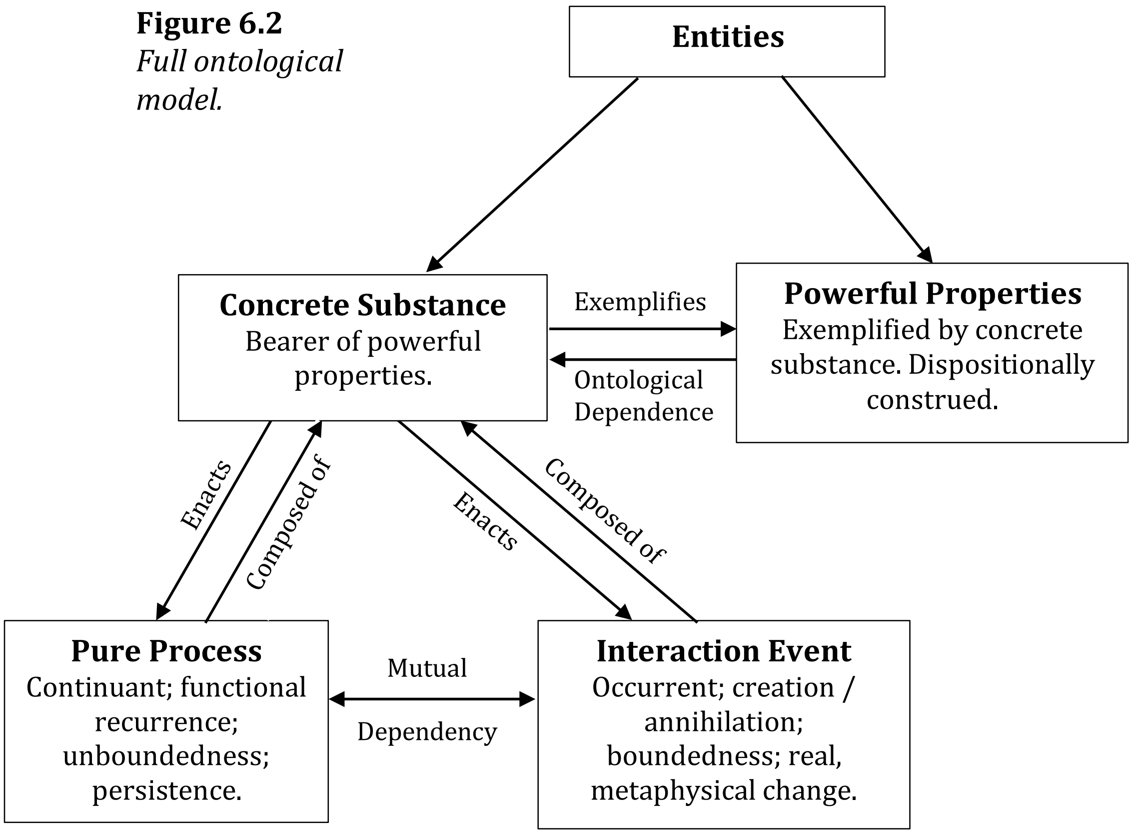
The ontological hierarchy described is proposed as compatible with both presentism and our best theories of physics. In the following section I show that the intrinsically spatiotemporal nature of concrete substance arises in virtue of this inter-dependence between the distinct categories of pure process and interaction event. This mechanism has been alluded to previously in accounting for temporal duration.

Before proceeding further there is a need to complete the ontological model with the addition of a fourth category, that of 'powerful property'. The category of powerful property will be seen to have an important role to play in accounting for causation. In particular, within Chapter 7 I recommend a realist, productive account of causation, compatible with the ontology proposed here, as a method that allows the presentist to avoid the problems encountered when causation is seen as an existence-entailing relation. Under this account, properties are regarded in a dispositional manner, as 'powerful' properties, whose causal role (as dispositions-to-do) is essential to them. Powerful properties may additionally have a *qualitative* aspect to them, such as the property 'redness'. The apple's redness is an intrinsic quality (associated with the presence of carotenoids), nonetheless it is also dispositional: it has the disposition to reflect light in the red wavelength.[136]

[136] This is similar to Heil's characterisation of properties as 'powerful qualities' (2012, p.61); such an approach blurs the distinction between the categorical and the dispositional.

The addition of powerful properties, dispositionally construed, completes the ontological model and this is shown in Figure 6.2, which illustrates the relations between the different categories employed. This is not implied to be an exhaustive ontological scheme, and it remains neutral on the status of, for example, propositions and other abstract entities. Nonetheless, it provides an ontological schema sufficient to explain the spatiotemporal nature of concrete reality, from a presentist perspective.

Figure 6.2
Full ontological model.



The arrows in Figure 6.2 describe the relationships that exist between the different categories. Concrete substance exemplifies powerful properties and the latter depend upon the former in the sense described by Tahko and Lowe's (2016, §1) notion of 'rigid existential dependence'. Pure process and interaction event are categories that represent modes of (propertied) concrete substance, or the dynamic *ways* that concrete substance is. Concrete substance enacts, or participates in, both pure processes and interaction events and, in doing so, it exemplifies persistence and real, metaphysical change, respectively.

In the remainder of this chapter I use the mechanism of Belkind's (2012) Primitive Motion Relationalism to argue that this proposed ontology for presentism is compatible with a reductionist account of B-theory relativistic spacetime. In § 6.8 I first outline Belkind's theory, I then argue that the core elements of Belkind's model structurally align with the categories of the presentist ontology I have proposed (§ 6.8.1). Though Belkind's model is equally compatible with an eternalist ontology, I argue (§ 6.8.2) that the boundedness of interaction events secures a uniquely presentist model of the structure of spacetime. I also provide an illustration, on the basis of a simple light clock, of how temporal duration can be understood as arising from the ontological categories proposed.

6.8 Deriving Spacetime – Primitive Motion Relationism

Belkind's (2012) Primitive Motion Relationalism is a relational theory of spacetime that derives both Galilean and flat[137] relativistic spacetime from an axiomatic system under which both uniform, unidirectional motion and the intersection of such motions are primitive.[138] The key definitions and axioms comprising Belkind's system, together with a summary of his argument, are set out in Appendix 2.

Belkind's theory is constructed from 'Paradigms of Uniform Motion' (PUMs); these are primitive entities exemplified by the motions of free particles, isolated systems and light signals. The model takes uniform, unidirectional motion as the fundamental state of physical reality. Belkind's reasoning is based on the 'criterion of isolation' which, he argues, is central to scientific practice. In order to investigate the properties of a system it needs to be isolated from its environment. Within Newtonian systems, the criterion of isolation provides that a system is isolated if and only if it moves with uniform, unidirectional motion (this applies to both free particles and composite systems). Given that the criterion of isolation occupies an *a priori* place in scientific practice, Belkind

[137] The term 'flat' refers to four-dimensional, Minkowski spacetime in the absence of matter. This is the spacetime of STR. The presence of matter leads to a curvature of spacetime, which is described by the Einstein Field Equations of GTR.
[138] Although Belkind derives both Galilean and relativistic spacetimes from his axiomatic system he has yet to extend this to the general relativistic case.

argues, 'it seems logical to take uniform unidirectional motion as a basic, fundamental state of physical systems' (p.60).

Events, or spacetime points (2012, p. 63), are the intersections of such motions (PUMs) and are also primitive. The spatiotemporal metrics[139] of flat, relativistic spacetime are then derived from the geometrical relations between events. In Chapter 2 (§ 2.5.1) I argue that time, as it functions within physical theory, is defined in terms of physical clocks, and such systems always involve motion, of one form or another. Temporal duration is therefore derivative of motion. This aligns with Belkind's theory which implies that any measured duration, or interval, between events is inseparable from the motion (PUM) that constitutes the process by which clocks are calibrated. Space and time are dependent on motion. As Belkind notes:

> The abstraction of duration and length from the process by which clocks and rods are implicitly calibrated generates the impression that duration and length exist independently of one another and independently of the motion of bodies. However, if the geometry of PUMs describes spacetime reality, the concept of duration and length should always be assessed as the duration and length that elapse between *events generated by uniformly moving objects*. (2012, p.76)

The spatiotemporal interval (ds^2) between events in spacetime is therefore given by the possible paths, or motions, of the light rays able to connect those events. The velocity (in other words, the *motion*) of light is invariant for all observers (regardless of their state of relative motion) and, as such, light provides an absolute standard of motion intervals. It is because of this that the spatiotemporal interval between any two events (or spacetime points) is the same for all observers, even though they may decompose this interval (motion) into different spatial and temporal components (it is this that gives rise to the

[139] A spatiotemporal metric is a measure of the (spatial and temporal) distance between points in spacetime. For Minkowski spacetime this is given by the Minkowski metric, ds^2, where $ds^2 = c^2\Delta t^2 - \Delta x^2 - \Delta y^2 - \Delta z^2$, where c is the velocity of light.

relativistic kinematic effects of time dilation and length contraction described in Chapter 3).

In championing a relational model of spacetime, Belkind (similarly, Brown, 2005) argues against the position that the reification of spacetime is needed in order to explain and determine (in a causal sense) the inertial motion of bodies. The latter is the view that regards spacetime as 'directing' bodies to move along its geodesics. For Belkind inertial motion requires no such explanation, in line with Newton's First Law of Motion inertial motion is a default state of matter.[140]

In postulating inertial motion as primitive, Belkind's model differs from other relational accounts of spacetime (e.g. Teller, 1987 and Dieks, 2001) that regard spacetime coordinates as physical quantities that are realised by objects. Belkind regards such an approach as laden with interpretive problems.[141] Aside from the success Belkind's model demonstrates in deriving both Galilean and Minkowski spacetime, its principal benefit is that Einstein's Principle of Relativity[142] is generated as a *natural consequence* of his model under which uniform motion (including light-waves) is considered primitive. This is not the case with other relational models (such as 'dynamical relationism'[143]), and even under the STR the derivation of the structure of flat relativistic spacetime requires that the Principle of Relativity is *assumed* as an axiom of the theory. In accepting the shortcomings of his version of dynamical relationism, Brown admits that under his theory it is just an 'unexplained, brute fact' (2005, p.143) that all the fundamental laws of physics happen to obey the Principle of Relativity. Yet, as Belkind suggests, 'the Principle of Relativity seems to beg an independent explanation since it would be a miraculous accident if it just

[140] Further arguments in support of a relational, over a substantival, view of spacetime are presented in Chapter 2 (in relation to the 'problem of time' within quantum gravity) and will not be further considered here.
[141] For example, position appears inherently relational in a way in which mass, as an exemplary physical quantity, is not.
[142] The Principle of Relativity asserts the equivalence of the laws of physics in all inertial reference frames.
[143] Dynamical Relationism reduces spacetime to the structure of dynamic laws; the latter serve to determine potential spacetime positions and velocities of bodies. Kinematic relativistic effects therefore arise from the underlying dynamics of physical processes. Such approaches are advocated by Brown and Pooley (2006), Brown (2005), Dieks (2001) and Teller (1987).

happened that all dynamic laws are Lorentz-covariant' (p. 56),[144] and it is only Belkind's theory that appears to offer such an independent explanation.

Additional support for an approach which sees motion as primitive is implied in a point made by Dorato (2007, p. 98). Dorato, in reviewing Brown's (2005) theory, notes that scientific revolutions often involve reclassifying, as 'natural', phenomena that were previously felt to require a causal explanation. He gives the example of the transition from Newtonian gravitational theory (which describes 'causal' gravitational forces) to the General Theory of Relativity. Within the latter a causal explanation is redundant since free-fall is considered the 'natural' state of bodies. But if free-fall is a 'natural' state of matter, then why should we not also consider inertial motion to be a natural state of matter, as indicated by Newton's First Law? Although Belkind has yet to extend his model to a derivation of the spacetime of GTR, it seems reasonable to conjecture that such an extension *is* possible and, if so, it seems likely to be arrived at by employing entities in free-fall as the primitive elements in the model.

In the following section I argue that the categories of pure process and interaction event, defined within the ontological model developed in this thesis, possess category features that structurally align with the axiomatic elements of Belkind's model. If the argument for alignment can be successfully made, this suggests that a presentist ontology can at least be shown to be compatible with relativistic spacetime of STR and its predicted kinematic effects, namely, length contraction and time dilation.

6.8.1 Alignment Between Belkind's Model and the Proposed Ontology for Presentism

Belkind's model is constructed solely on the basis of two, primitive, structural elements: uniform, unidirectional motions (PUMs) and events (the intersections of these motions). From these two principal elements, together with certain

[144] Lorentz-covariance is a property of dynamical equations such that if the equations in which it is written hold true in one inertial reference frame, then they hold true in all inertial frames.

supplementary definitions and axioms (set out in Appendix 2), both Galilean and flat relativistic spacetime are derived.

The first fundamental element of Belkind's model is uniform, unidirectional motions (PUMs). These are exemplified by free particles, isolated systems and light signals, all of which exemplify inertial motion. Inertia is a property such that an object in motion *remains* in motion, whilst an object at rest remains at rest, unless acted upon by an external force. Inertial motions (and so PUMs) exhibit a continuity, or recurrence of an activity, namely, continuing to move with a uniform velocity. Consequently, PUMs have a functional alignment with the category of pure process under the proposed ontology, as defined in § 6.7. PUMs, as pure processes, are also unbounded. Inertial motions continue on in existence unless, and until, they intersect with other motions; they thereby exemplify persistence (defined as continuing existence) – a defining feature of the category of pure process.

The second primitive element within Belkind's model is that of 'event'. He defines events as intersections between motions (2012, p. 64). Though Belkind states that 'since an event is a relation between PUMs, it is not a primitive entity' (p.63), in correspondence I have had with him (21/09/2016) Belkind clarifies as follows: 'the notion of intersection comes out to be a primitive relation between two motions. So an intersection is not an entity like a point or a particle, but a relation that holds or does not hold between two motions.' Thus, for Belkind, events *as intersections* are primitive, though they are not primitive *entities*. This aligns structurally with the category definition of interaction event under the proposed ontology: interaction events are defined as *interactions* of pure processes (§ 6.7) and interaction, as with Belkind's concept of intersection, is primitive.

Belkind's derivation of the structure of relativistic spacetime is built upon these two fundamental elements - motions (PUMs) and intersections (events): 'The approach here therefore constructs spacetime from geometric relations between motions, first defining events as intersections between motions, and then defining geometric relations between those events' (p.63). The functionally relevant feature of events, in Belkind's derivation of a relativistic spacetime, is that events are *intersections* of primitive motions and this feature (described as 'interaction') is present within the category definition of interaction event under the proposed ontology. Interaction events are thereby spacetime points. Similarly, the functionally relevant property of PUMs in Belkind's derivation is continuing, uniform motion. As the continuity of some functionally specified dynamic (in this case, motion), PUMs fall under the category of pure process. Pure processes, as is the case with PUMs, define the intervals between spacetime points.

I have argued for a functional alignment between the structural elements of Belkind's model and the proposed ontological categories for presentism and, to this extent, the ontological model is compatible with a reductionist view of the structure of relativistic spacetime. Nonetheless, Belkind's model is equally compatible with an eternalist ontology that also adopts a reductionist account of spacetime. Belkind himself is neutral between presentism and eternalism, though he does suggest that neither provides an adequate ontological account of the spacetime of STR (p. 115), and that a different ontological interpretation is required.[145] I therefore need to show how a uniquely presentist model is achieved; I explain this in the following section in terms of the boundedness of interaction events. I then illustrate how temporal duration arises from the ontological categories proposed.

6.8.2 A Presentist Version of Belkind's Model

As it stands Belkind's Primitive Motion Relationism is equally compatible with an eternalist ontology, one which regards all motions (PUMs) and all intersections of motions (spacetime events) as equally real. Belkind's theory is concerned with deriving the *structure* of relativistic spacetime, within a paradigm aligned with the philosophical commitments of relationism, rather than representing the underlying ontology of the corresponding reality.

[145] Belkind takes the presentist to be committed to absolute simultaneity or the existence of a privileged inertial reference frame (2012, § 4.3); this is contrary to the approach taken in this thesis.

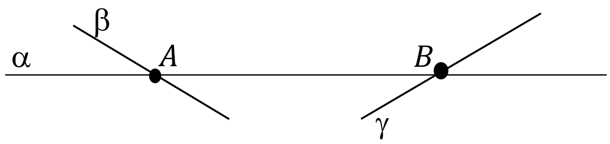
Nonetheless, a uniquely presentist model of the structure of spacetime may be secured using the feature of the boundedness of interaction events, introduced in § 6.7.1. Boundedness, it will be recalled, is an existential notion which reflects that interaction events (in addition to being *interactions* of pure processes) are points at which entities come into and go out of existence. The incorporation of absolute creation and annihilation within the category of interaction event has the result that interaction events (which, in alignment with Belkind's model, are intersections of PUMs and so spacetime points) do not exist eternally. An ontological framework that aligns in a structurally relevant manner with Belkind's model allows both a presentist and an eternalist schema to derive the structure of relativistic spacetime; both schema would describe the *same* structure given by the Minkowski metric, ds^2. However, in the case of the eternalist ontology the intersections of PUMs are not points of absolute creation and annihilation. For the eternalist all intersections (and so events, or spacetime points) exist eternally, and on an ontological par with one another. This contrasts with the proposed presentist model, under which the intersections of PUMs (interaction events) are points of absolute creation and annihilation, in this way spacetime events reflect real, metaphysical change.

At this point it might be questioned how a presentist reality could be structured in the manner described by the Minkowski metric, ds^2 when the only spacetime events that exist are those that exist presently. In particular, how can there be an interval (ds^2) between events when one of those events is no longer present? I address this question in the following section.

6.8.3 Accounting for Duration

I use the example of a simple light clock to illustrate how the proposed, presentist ontology can give rise to spatiotemporal intervals (or duration), and a spatiotemporally structured reality, in the absence of an eternally existing framework of spacetime points, or events. This explanation also provides a sense in which the present is temporally extended.

Under Belkind's model events, or spacetime points, are intersections between primitive uniform motions and the spatiotemporal interval (ds^2), or duration, between events is given by the primitive motion that connects them. In the illustration below, motion, α, intersects with motion, β, and this defines event, *A*. Motion, α, subsequently intersects with motion, γ, and this defines event, *B*. Events, *A* and *B*, are connected by (have in common) motion, α, which defines the spatiotemporal interval between them.



Under the presentist version of this model a spacetime event is not only a point of interaction (or 'intersection') between pure processes (e.g., primitive uniform motions) it is also the point at which a pure process comes into existence and/or goes out of existence (§ 6.7). A notion of duration (spatiotemporal interval) is illustrated using a simple light clock (Figure 6.3) in which light rays are reflected between two opposing mirrors. In this example the pure processes that interact are the motions of light rays and the mirrors (as persisting entities).

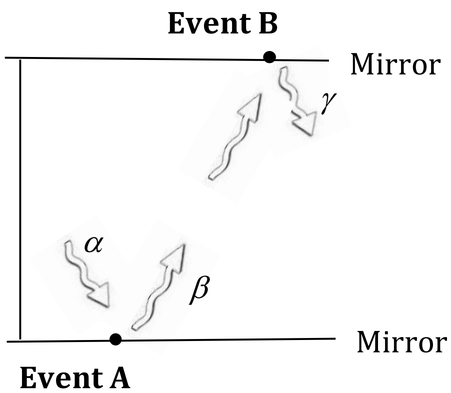


Figure 6.3
Simple Light Clock

Under the ontology proposed here, event A is an interaction event (defined in § 6.7): an interaction between two pure processes (motion α and the persisting mirror) that creates a new pure process, β, (the motion of the reflected light signal). In alignment with Belkind's model, event A is also a spacetime point (§ 6.8). Event B is a separate spacetime point, and is the interaction event (between the newly created motion β and the opposing mirror) at which β is annihilated. Event A and event B are separated by a spatiotemporal interval (ds^2) which is given by the motion of β between A and B. This interval is a *duration*, in particular it is the lifespan of the motion between the point of its creation and the point of its annihilation. It is important to emphasise that motion is defined in terms of a change in distance over time, and so any interval of motion (dx/dt) is a *spatiotemporal* interval (rather than an interval of *temporal* duration).

Imagine a two-event universe that consists solely of events A and B, and the motion of the light signal, β, between them. Since there are only two events in this universe (the events that are the creation and annihilation of β) there are only two spacetime points (A and B), and these equate with the beginning and end of this universe. Spacetime points A and B are also spatiotemporally related, and their spatiotemporal relation is given by the interval (ds^2) provided by the motion of β. Such a two-event universe is the simplest universe that can exhibit a spatiotemporal structure.

What is it that can be said to be present in this universe? Under Existence Presentism (§ 4.8) presence is existence. This universe comes into existence at the creation event, A, and so spacetime point A is the 'beginning' of what exists and so is the 'beginning' of what is present. Conversely, the annihilation event, spacetime point B, is the 'end' of what is present. This means that what is present (what exists) in this universe is the continuing motion of the light signal, β, between A and B. What is present is what *continues* in existence. The motion of β between points A and B therefore gives rise to the spatiotemporal extent, or duration, of the present. Since there is nothing, in this simple universe, that comes into or goes out of existence other than at A and B, the spacetime points A and B represent the boundaries of the present (as existence) and the interval between these, given by the motion of the light signal, is the spatiotemporal extent, or duration, of the present.

It will be recalled from § 6.7 that the two ontological categories of pure process and interaction event reflect persistence and real, metaphysical change respectively. Thus a present that contains both creation and annihilation (real, metaphysical change) *and* continuing motion (persistence) can exemplify objective spatiotemporal structure, compatible with the structure of relativistic (B-series) spacetime. This structure is defined by the interval (ds^2) that arises from the continuing motion of β between its points of creation and annihilation. It is in virtue of the inter-dependence of real change and persistence (and the ontological categories reflecting them) that the present unfolds and is spatiotemporally structured – it both moves on and continually changes.

A final point to note is that the spatiotemporal relation between spacetime points A and B (the interval, ds^2, given by the motion, β) is not a *cross-time* relation, in the sense of implying the existence of times (or spacetime points) beyond the present. The interval relates spacetime points A and B, but A and B are not beyond the present, rather they are creation and annihilation events that define the boundaries of what is present. In this simple universe a spacetime relation can obtain between two spacetime points without implying the existence of anything that is non-present. This, admittedly simple, example shows that the presentist can, by adopting Belkind's relational model of spacetime together with the ontology proposed in Chapter 6, explicate some notion of a present that is extended and spatiotemporally structured.

6.9 Conclusion

In this chapter I have proposed an ontology for presentism which reflects the presentist's commitment to real, metaphysical change. I also hope to have shown that it is an ontology that is compatible with a reductionist approach to relativistic (B-series) spacetime.

The interplay between pure process and interaction event gives rise to a present that continues on, and in doing so reflects the primitive nature of persistence. To this extent the present has 'duration' and is 'extended'. The occurrence of interaction events, within the present, reflect real (metaphysical) change. As such the present, as that which exists, is continually changing. The present continues on through continually changing and it is in this way that reality is objectively tensed.

The present is also spatiotemporally structured. Interaction events (spacetime points) are the boundaries that define the objective and measurable spatiotemporal intervals (ds^2) of relativistic, Minkowski spacetime. Since, under the presentist ontology, interaction events are also points of objective creation and annihilation, Minkowski spacetime emerges as the structure of an objectively *dynamic* reality. In this way the compatibilist presentist is distinguished from the eternalist, for whom Minkowski spacetime is the structure of an objectively *static* reality (§ 4.7).

The compatibility of the proposed ontology with the spacetime of STR does not, as such, indicate its potential for alignment with either GTR or emerging theories of quantum gravity. Nonetheless, the discussions within Chapter 2, of the problem of time within quantum gravity, indicate a growing perception that there is a need for a new ontology of spacetime. It is also argued (§ 2.5.1) that the concept of time within physical theory is derivative of objective change, and therefore that physics *can* countenance an objectively dynamic reality. It is tentatively suggested, therefore, that an alternative ontology for spacetime, one that sees time as derivative of an objectively dynamic reality, might be the appropriate way towards resolving some of these conceptual issues.

In the remainder of this thesis I show how the proposed approach to presentism can help to ameliorate two particular issues that arise for the presentist: cross-time relations and the asymmetry of fixity.

CHAPTER 7 – CROSS-TIME RELATIONS & CAUSATION

7.1 Introduction

Normal language usage and scientific modelling both make extensive reference to what are ostensibly cross-time relations (CTR), such as causal relations. For example, yesterday's storm is described as causing today's flood. Comparative relations can also be suggestive of a relation that is cross-time. We might consider the man next door to be as tall as Socrates. Even simple reference to past events and individuals assumes that relations between those entities hold. Most presentists would wish to be able to subscribe to the truth of the propositions that contain these references. After all, one of the principal attractions of presentism is that it reflects a common-sense viewpoint.

CTR are problematic for presentists. At the core of the issue lies the assumption that, in general, for a relation to hold its relata must exist. Inman (2012) refers to this as the 'principle of relations': in the case of the two-place relation, it is the principle that 'necessarily, if an entity *a* stands in a relation *R* to an entity *b,* then *a* and *b* exist' (p. 55). This, in turn, suggests that, contrary to presentism, non-present things, such as yesterday's storm, must exist.

In this chapter I attempt to address the problem of CTR using the model of presentism developed so far. In the first two sections I discuss the main approaches presentists employ in dealing with CTR and I highlight their shortcomings. I then set out an alternative approach, in line with the ontology for presentism outlined in Chapter 6. The first step is to argue, on the basis of a distinction between internal and external relations, that the only relations of real concern are the paradigmatically external relations: these are spatiotemporal and causal relations. The strategy I then follow is to formulate a presentist account of causation under which causation, at the level of metaphysical analysis, is not a relation. Consequently, cross-time causal claims are not relational claims and so do not imply the existence of non-present entities. Nonetheless, I concede that under the model proposed cross-time spatiotemporal relations remain problematic, and refer to other presentist strategies for dealing with these.

7.2 Presentist Accounts of Cross-Time Relations

Presentists have employed a variety of approaches to meet the problem presented by CTR and these have been widely discussed.[146] These approaches generally fall under one of two main strategies. The presentist can accept that true CTR claims are made true by cross-time relations but deny that such relations are, in a manner that defeats the presentist, existence-entailing. The 'principle of relations' is rejected because the relevant claims do not imply the present existence of *both* relata.

Under the second strategy, the presentist accepts that relations are existence-entailing but posits presently existing entities to stand as the relata. Ciuni and Torrengo (2013) describe the former strategy as 'eliminativist' and the latter as 'reductionist' stances. I consider each of these strategies in turn and highlight their limitations. I argue that a productive account of causation offers a route to circumventing the problems raised by causal CTR claims, and is better aligned with the presentist ontology developed thus far.

7.2.1 Eliminativist Approaches

The eliminativist strategy asserts that true CTR claims are made true by CT relations. However, since the principle of relations is rejected, cross-time relations do not imply the existence of both relata (only the presently existing relatum exists).

For example, Chisholm's (1990) 'overlapper' approach considers any CTR as a sequence of overlapping relations. This allows a present entity (e_3) to stand in a relation to a past entity (e_1) in virtue of standing in some *other* relation with another present entity (e_2). For example, Emily (e_3) stands in the relation *being the grand-daughter of* to the now deceased Edna (e_1), in virtue of standing in the relation *being the daughter of* to her currently living mother, Elisabeth (e_2). The cross-time relational claims made do not, when translated correctly, predicate relations between non-present entities. 'Emily is the grand-daughter of Edna' is

[146] For example, in Adams (1986), Bigelow (1996), Zimmerman (1998), Sider (2001), Crisp (2003), and Markosian (2004), De Clercq (2006), Ciuni and Torrengo (2013), Tallant (2018), Ingram and Tallant (2018).

translated, in tensed terms, as 'Emily is the daughter of Elisabeth and WAS (Elisabeth is the daughter of Edna)'. Tensed operators permit the existence of entities to overlap and so bear relations in a manner that is not existence-entailing. This allows the existence of Elisabeth to overlap the existence of both Edna and Emily.

In criticism, Crisp (2005) denies that the overlapper mechanism provides *equivalent* translations of the given propositions. The original proposition describes Emily as bearing a direct relation to her deceased grandmother, whereas the translation describes her as bearing a direct relation only to her mother. In a similar vein, Davidson (2003) argues that the relation $e_3\boldsymbol{R}e_1$ (*being the grand-daughter of*) is not the *same* relation as the relation $e_3\boldsymbol{R}e_2$ (*being the daughter of*) yet it is in virtue of the latter that the former is said to hold. If the 'in virtue of' is not grounded in a similarity of relation, then surely *any* relation should be sufficient. Yet this would render 'in virtue of' devoid of any explanatory force. Restricting the overlapper mechanism to operate only on identical relations (e.g. *being the daughter of*) fails to help. The correct CTR is not generated since Emily is not the daughter of Edna. Nonetheless, a defender of Chisholm's account might retort that the relation *being the grand-daughter of* is the ancestral[147] of the relation *being the daughter of* and it is *this* that grounds the 'in virtue of'.

Ciuni and Torrengo (2013) make a similar point to Davidson, though in this case they refer to relations between properties:

> For one of the explanatory strategies which overlapping admits is that – for instance – in the past the dinosaurs were related to the property of *being blue* and that that property is now related to me […] If the abstract properties that do the work can be *any* abstract property, then there would be properties that ground past truths while not being "about" the same as the true claims are about. (pp. 224-225)

[147] Frege was the first to propose 'ancestral relations' in his *Begriffsschrift* of 1879, as described in Zalta (2020).

Underlying the eliminativist stance, that cross-time relations are not existence-entailing on both relata, is an implicit rejection of Quine's conception of ontological commitment. Hinchliff (2010) credits Crisp (2005) with highlighting the underlying assumption of an intimate connection between predication, quantification and existence. Hinchliff refers to this as the 'triangle argument': true predication implies that there is an entity to which the predicate applies and, since quantification requires existence, the entity in question must exist. In rejecting the 'triangle argument', Hinchliff offers an alternative, 'non-committal' quantification based on the notion of a 'particular' quantifier (**P**x). This ranges over past, present and future objects without existential implication and is to be distinguished from the, more restricted, 'existential' quantifier that ranges only over existing objects. This rejection of a classical-logical account of quantification allows the presentist to quantify over non-existing objects which can thereby presently exemplify properties and stand in relations. Undoubtedly this is a revisionary solution but, as Inman (2012) argues, such an approach cannot be defeated by arguments (such as those of Davidson, 2003) that simply beg the question against the presentist's rejection of the 'principle of relations' and the consequent denial that CTR are existence entailing. That may be, but of equal weight is the criticism that Hinchliff's invocation of the notion of particular quantification appears to be a rather *ad hoc* move.

Crisp (2005) attempts to undermine the foundations of the 'triangle argument' by arguing that the success of the objector's case rests on a conjunction of two claims. The first is the claim that the sentences concerned express Moorean facts. The second is that they predicate non-present entities. Crisp argues that if the first claim is true then the second is false.

Moorean facts are 'something like: a true proposition only a fool could fail to believe and believe firmly' (Crisp, 2005, p. 11). For example, the fact that there are material objects or, as Armstrong (1999, p.79) suggests, the fact that 'things move'. Lewis (1999, p.418) describes this type of 'everyday knowledge' as that which 'we know better than we know the premises of any philosophical argument to the contrary'.

Crisp maintains that if claims such as 'Caroline is the daughter of JFK and Jackie' are true iff, quantifying unrestrictedly, there *is* something that is JFK, then they cannot also express Moorean facts. Although Moorean evidence might be available (e.g. medical records, newspaper reports, etc.) to support a tensed rendition of the claim (i.e. *WAS*: Caroline is born to JFK and Jackie) they do not suffice as Moorean evidence for sentences such as 'Caroline bears the *daughter of* relation to JFK and Jackie'. This is because the latter entails 'quantifying unrestrictedly there *is* something that is identical with JFK' and no amount of evidence available could support the truth of *that* claim. The objector cannot have it both ways. If true CTR claims have existential commitments then they cannot also express Moorean facts, since there can be no evidence sufficient to support them. Conversely, if the claims *do* express Moorean facts they cannot be predicative of non-present entities, on the same grounds.

Nonetheless, Crisp (2005, p.14) notes that he faces a difficulty presented by cross-time causal relations. It certainly seems to be the case that a Moorean fact grounds the truth of 'yesterday's downpour (e_1) caused today's flood (e_2)'. Yet we also wish to assert the existence of a causal relation between the two which implies the predication of non-present entities.

In denying the existence-entailing nature of relations, the eliminativist strategy appears to require a revisionary approach to quantification. Though this is not, in itself, sufficient reason to reject the strategy, as Crisp notes causal relations appear to present particular problems that are not easily remedied. This point is reinforced by Sider (1999) who acknowledges that his own eliminativist approach[148] struggles with causation where this is seen as a relation between temporally distinct entities.

7.2.2 Reductionist Approaches

For the reductionist, true CTR claims are made true by relations, but in this case they are not *cross-time* relations. The reductionist holds to the principle of

[148] Sider's approach provides that CTR supervene on currently possessed intrinsic properties and properties that *were* possessed by past entities described in tensed terms. However, this proves difficult for certain spatiotemporal and causal claims that require spatiotemporal individuation of entities no longer in existence (1999, pp. 335-338).

relations and so maintains that all relations are existence entailing on both relata. In order to avoid the problematic ontological commitments presented by cross-time relations, the reductionist strategy involves positing presently existing entities as the truthmakers for the relational sentences involved. Ostensibly *cross-time* relations in fact relate presently existing relata. The thought here is that, as De Clercq (2006, p.400) suggests, 'the ontological commitments of common sense attributions do not always lie at the (grammatical) surface'. The presently existing surrogate entities may be either concrete or abstract. Concrete surrogates include present traces of the past, such as Lucretian properties (Bigelow, 1996). Abstract entities include ersatz times (e.g., Crisp, 2007 and Bourne, 2006), facts (De Clercq, 2006), or properties such as thisnesses (Adams, 1986, Ingram, 2016). I describe each of these in what follows.

An influential proponent of the reductionist approach is Bigelow (1996). Bigelow considers that the principle of relations is defensible and should be accepted by the presentist. He sees it as defensible because it is underpinned by the truthmaker principle (every truth requires a truthmaker or 'truth supervenes on being' (1996, p.38)).[149] If a proposition that attributes a two-place relation is true then there must exist relevant relata.[150] Bigelow therefore posits 'Lucretian properties' to stand as presently existing truthmakers for past tensed propositions. Lucretian properties are concrete 'world properties' possessed either locally or globally as a result of events *having* occurred. For example, a property such as *being where Richard III died*.

One criticism of Bigelow's approach is that it fails the 'aboutness' criterion (Ingram, 2019, p.110). The proposition <Boudica was fierce> does not appear to be *about* the world yet, under Lucretian Presentism, it is made true by a property that is a property of the world.

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[149] It should be noted that the truthmaker principle is not universally accepted. Beebee and Dodd (2005) provide an overview of the contemporary debate, which includes the question of how well-motivated the principle is, and its explanatory merit.

[150] However, Bigelow concedes that relations that involve intentionality (e.g., those of *desiring*, *seeking* and *admiring*) could conceivably be considered exempt from this; Cuini and Torrengo (2013, p.214) concur.

Other accounts make use of abstract entities to stand as the relata for CTR. Abstract entities (whether types, properties or propositions) can be employed to re-describe ostensibly cross-time relations and so avoid the inclusion of non-present times or entities. In the case of causal relations, De Clercq (2006) maintains that *facts* constitute the primary relata: 'the fact that the world *was* a certain way is a current fact about the world, and one which may be invoked to explain why the world now *is* a certain way' (p.389). Causal relations thereby do not require any temporal distance to be bridged. Aside from facts, abstract properties, such as individual essences, haecceities or thisnesses (e.g. Adams, 1986, Ingram, 2016) can be employed in a similar manner to represent past entities. Once they come into existence such properties are eternal and, unlike standard properties, do not require bearers (or at least do not require the continuing existence of their bearers). Ingram's account will be considered in more detail in § 7.6 where I deal with spatiotemporal relations.

The use of abstract entities, as surrogates in the present, might be criticised for being ontologically extravagant and so at odds with the ontological parsimony that advantages presentism. This is mitigated, to some extent, within ersatz presentism (e.g. Crisp, 2007 and Bourne, 2006).

Ersatz presentism avoids ontological extravagance to a certain extent since it posits an abstract set of propositions to represent all past and future times, instead of having abstract entities that represent individual concrete particulars. These propositions stand as a maximal description of reality at a given time. This particular strategy, however, presents a risk of incompatibility with relativistic physics in so far as it appears to rely upon reality being sliced into unique temporal portions, each with its own maximal set of propositions. This contravenes relativity theory (Chapter 3), which denies the existence of unique, universal hyperplanes of simultaneity. Ingthorsson (2019, p. 58) and Mozersky (2015, p.44) also point to the dangers that this mechanism poses to the ontological priority of the present, if ersatz times are seen as truthmakers. This is not so serious in the case of past times since the corresponding ersatz times could have the same (ontological) status as present traces of past events. However, this cannot work for future ersatz times. Unlike Lucretian properties (*qua* concrete), the epistemic status of ersatz times is also unclear: 'It is still the case that we learn about dinosaurs from fossils in the ground and not by accessing a realm of abstract propositions' (Ingthorsson, 2019, p.58). Abstract entities do not justify our beliefs about the past but physical records can.

One problem that appears to the fore is that if the presently existing surrogate entities (such as ersatz times) *represent* previously existing states of affairs, and if representation is *itself* an external relation, then the problem remains. The reductionist who concedes the existence-entailing nature of relations seems still to be committed to the existence of those past states of affairs. A more significant concern against the use of abstract entities is that paradigmatically external relations (namely spatiotemporal and causal relations) seem inextricably bound up with the nature of concrete reality and, to this extent, must in some manner relate *concrete* (rather than abstract) entities. This seems true irrespective of the particular model of spacetime or causation to which one subscribes.

There is a more general point to be made here too: *any* account that depends upon presently existing surrogates for CTR (whether concrete or abstract) appears to fall foul of Tallant and Ingram's (2015) 'nefarious argument'. As referred to previously (§ 5.4.4), Tallant and Ingram deny that the presentist requires presently existing truthmakers for CTR, or indeed for any true claim, *p*, about the past. The argument proceeds as follows. Any presently existing truthmaker, E, the presentist might adopt must exist *in virtue of* some other entity, *e*, *having existed*. This has to be the case in order that E does its job in providing sufficient ontological grounds for the truth of *p*. And if the presentist concedes that such an *in virtue of* relation does obtain[151] between *e* and E (and this seems unavoidable) then E is redundant. If the *in virtue of* relation *does* hold then it is a sufficiently strong modal relation, in and of itself, to provide the right ontological grounds for the truth of *p*. They therefore recommend that the presentist subscribes to a 'nefarious strategy of cheating': there is no requirement for presently existing truthmakers since facts about the past (and,

[151] It is a separate challenge for the presentist to deny that this 'in virtue of' relation is existence-entailing.

similarly, singular propositions) are simply constituted by entities that *used* to exist, but do not exist *now*.

7.2.3 Conclusions

Despite the various strategies employed, cross-time relations do present problems for the presentist. Reductionist strategies have limitations associated with their requirement for presently existing surrogates. Viewed as concrete properties they need to pass the 'aboutness' test. Regarded as abstract properties, they fall foul of the sense that both spatiotemporal and causal relations essentially relate *concrete* entities. However, more generally, the employment of presently existing surrogates *in any guise* is undermined by Tallant and Ingram's (2015) 'nefarious argument'. Eliminativist approaches, on the other hand, require a revisionary approach to quantification. Although the eliminativist denies the existence-entailing nature of relations, cross-time causal relations, nonetheless, present particular problems, and this is because causation is seen as a *relation* between temporally distinct entities. In what follows I utilise the ontology proposed in Chapter 6 to develop an alternative position to the eliminativist and the reductionist accounts of causal CTR; this position hinges on regarding causation as *production* rather than as a relation between temporally separated entities.

7.3 Dealing with CTR under the Proposed Account

The approach I take is, firstly, to draw a distinction between internal and external relations and, then, to adopt the position that, where they occur, all genuine concrete relations are external. Given this, the strategy that follows is to adopt an account of causation under which causation is not a relation. I then describe why the account does not seem to offer a mechanism to deal with problematic cross-time spatiotemporal relations.

7.3.1 Internal Versus External Relations

Simons (2010) draws a distinction between 'external' and 'internal' relations, for a true relational claim *aRb*, as follows:

> If it is possible that *a* and *b* both exist and it not be the case that *aRb*, then if *aRb* we say the relational predication is true externally. If it is not possible that *a* and *b* both exist and it not be the case that *aRb*, then where *aRb* we say the relational predication is true internally. (2010, p. 203)

The position that follows from this is that internal relational predications do not require relational truthmakers: the existence of *a* and *b* suffices to ground the truth of the relevant relational claim. Suppose Simmias bears the *is taller than* relation to Socrates. The truthmaker for this relational claim can simply be provided by Simmias, together with his property of *being 6ft tall,* and Socrates, with his property of *being 5ft 8 inches tall*, without recourse to an additional ontological entity: the relation *being-taller-than*. Such internal relations involve 'no addition of being' (Heil, 2012, p. 145); they are not genuine, concrete relations in the ontic sense. Bourne (2006) describes these as 'determinables' (p.96), rather than 'relations' for this reason.

Heil (2012, Ch 7) traces to Russell (1903, §214) the notion that relations are ontologically fundamental and, consequently, the idea that all relations require relational truthmakers. For Heil, there is an implied epistemic fallacy at work here. There is no necessity for an exact, or one-to-one, isomorphic 'mapping' between our conceptual frameworks and the ontological structure of the universe. This means that the truth of any conceptual representation of the world (whether in language or scientific theory) does not guarantee that it tells us what the universe must be like (ontologically) if that theory is true; hence, for example, the divergent philosophical interpretations of quantum theory. Analogously, although true relational claims are ineliminable in our representations of the universe, they need not be made true by relations, and claims involving internal relations provide such examples.

This distinction between internal and external relations provides the presentist with a means of dealing with CTR in a presentist-friendly fashion. By construing cross-time relations, as far as possible, as internal relations they can be handled without the associated existence-entailing commitments. Sider (1999, pp. 332-

336), though not a presentist himself, advocates dealing with ostensive cross-time claims, such as 'Tim is as tall as Socrates', as predicating internal relations. Their truth supervenes on currently possessed intrinsic properties (the property that Tim possesses of *being 5ft 8in tall*) and properties that *were* possessed by past entities, the latter being described in tensed terms (WAS: Socrates is 5ft 8in tall).

The problem, as Sider himself concedes, is that this mechanism does not work for paradigmatically external relations, such as spatiotemporal and causal relations. External relations, as defined, are ontically significant and involve an 'addition of being' over and above the entities so related. This means that an additional strategy is required, and this is proposed in what follows.

7.3.2 Spatiotemporal and Causal Relations – Paradigmatically External Relations?

As Heil (2012, p.146) notes, spatiotemporal and causal relations, as paradigmatically external, appear 'ineliminably relational'. As such, if *a* and *b* exist and *aRb* (where *R* is a given spatiotemporal relation) then it is also possible that *a* and *b* exist but not the case that *aRb*. The spatiotemporal relation between *a* and *b* is something over and above the existence of the entities themselves. It is possible that the pear tree in the garden, at the time of writing, and the flood on an adjacent road, two weeks ago, exist exactly as they are (or were) and yet stand in a slightly different spatiotemporal relation. God might have created the universe exactly as it is (qualitatively speaking) yet altered the relative spatiotemporal location between these two events.

The same appears true of causation. Standardly, causation is considered a relation between distinct entities such that causes temporally precede and are contiguous with their effects. The relations between causes and effects are also characterised by regularities governed by contingent causal laws. As such, the causal relation is explicated in terms of features external to the entities so related, and this suggests that causation is an exemplary external relation. In the example where yesterday's downpour caused today's flood, the contingent causal laws in play might involve the presence of unseasonably dry ground that permits an accumulation (rather than the absorption) of water. Equally, there is a possible world in which both events occur but are *not* causally related, in this world yesterday's downpour also precedes today's flood but the latter was caused by a burst water main at the top of the road.

Nonetheless, the argument that causal relations, in particular, are genuine external relations does rely upon certain conceptual assumptions. For example, under a Humean model of causation, causation is an external relation between temporally distinct entities formulated in terms of constant conjunction. It remains an option, therefore, for the presentist to provide an alternative, more presentist-friendly conceptual model under which an ostensibly external relation either comes out as internal, or is revealed not to be a relation after all.

In what follows, I provide an account of causation, compatible with the ontology developed in Chapter 6, that denies that causation is a relation. If causation is not a relation it does not follow that the entities referred to in causal claims stand in cross-time relations.

7.4 A Metaphysical Analysis of Causation

Hall (2004, p.225) highlights that our everyday understanding of causation, *qua* relation, involves two separate concepts: 'counterfactual dependence' and 'production'. In this section I argue that only one of these, production, provides an adequate analysis of causation at the *metaphysical* level. A productive account of causation also has advantages for a presentist model. I disagree with Hall that causal production is a relation, and this allows the problems associated with CTR to be avoided. In section 7.5, I propose a productive account of causation that combines elements from both causal process theories and dispositional accounts of causation.

The first concept described by Hall is *counterfactual dependence*: if the cause-event had not occurred, the effect-event would not have occurred. Counterfactual dependence represents causation as a *relation* between temporally *distinct* entities (generally events). As such, a counterfactual account brings with it ostensive implications that causation is a CTR. The second concept Hall describes as a relation of *production*: this is the sense in which the cause ‘generates’ or ‘brings about’ the effect. These distinct concepts of causation align with two opposing approaches in the literature to an analysis of causation. Reductive analyses of causation explain causation in terms of non-causal features of reality (such as regularities or counterfactual dependence). In opposition, productive accounts of causation tend to be associated with a realism about causation, under which causation reflects a fundamental feature of the world that is not reducible to anything non-causal. Nonetheless, any successful analysis of causation needs to be able to provide an explanation of how both these features are a part of our everyday concept of causation.

7.4.1 Counterfactual Theories Versus a Productive Account

Counterfactual theories of causation hold sway as the dominant model for causation within the philosophical literature.[152] The idea that there is *nothing more* to causation than counterfactual dependence is generally considered to have originated from Hume’s (1739) now famous quotation in which he combines both a regularity and a counterfactual analysis of causation:

> […] we may define a cause to be *an object followed by another, and where all the objects, similar to the first, are followed by objects similar to the second*. Or, in other words, *where, if the first object had not been, the second never had existed* (1739, sect VII, §60)

However, the rigorous development of counterfactual theories relied upon the elaboration of possible world semantics by Lewis (1973, 1986b).

Despite the implications of cross-time relations, there are presentist-friendly counterfactual accounts of causation.[153] Nonetheless, counterfactual accounts

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[152] For an overview of counterfactual theories of causation see Paul (2009).

[153] For example, Crisp (2005) describes a Humean account which allows the presentist to reduce a causal relation between e_1 and e_2 to a counterfactual relation between tensed propositions concerning e_1 and e_2. Similarly, a regularity theory approach might reduce causal relations to relations concerning the constant conjunction of events, formulated in terms of tensed propositions about event-types. Non-reductive approaches are also available. Adams (1986) and Bigelow (1996) argue for a primitive relation of causation, but not one that obtains between *events*, rather, it obtains between *propositions* concerning the occurrence of the relevant events, e_1 and e_2.

do suffer well-discussed difficulties,[154] though the primary argument to be advanced here is that counterfactual dependence is merely *symptomatic* of causation going on, rather than constitutive of causation. In doing so I adopt a realist view of causation.

In a realist vein, Ingthorsson (2019) argues that it is causation that explains counterfactual dependence (rather than the converse), since the acceptance of counterfactual claims as true presupposes causal knowledge. The counterfactual claim 'if there hadn't been lightning there wouldn't have been thunder' can be asserted as true only by someone who understands that thunder is the sound *caused* by lightning. Further, this belief only became justified following the scientific discovery connecting atmospheric electrical discharges (lightning) with the production of a subsequent sound wave (thunder). Ingthorsson concludes 'it is our understanding of the causal connection that determines whether we accept or reject the counterfactual, and, as far as I can tell, the same is true for every causal counterfactual' (2019, p.8).

In the following section I argue the case that counterfactual dependence is merely symptomatic of productive causation, at the level of a metaphysical analysis. In addition to the potential problem that arises from the cross-time nature of the counterfactual relation, this provides further good reason for the presentist to reject a counterfactual account of causation. I then suggest positive reasons for the presentist to adopt a productive account of causation instead, since this aligns well with the ontology presented within Chapter 6.

7.4.2 Counterfactual Dependence as Symptomatic of Productive Causation

Hall (2004) argues that counterfactual dependence and production should be regarded as two '*distinct concepts of causation*' (p. 226) because neither is sufficient to account for all features of causation. Specifically, over-

[154] For example, there are difficulties in handling cases of pre-emption (Schaffer, 2000), double prevention (Hall, 2004, p.241), and over-determination (Collins, Hall, & Paul, 2004; Moore,2009, ch.17). Counterfactual accounts can also lead to cases of spurious causation (Collins, 2000) and (Kvart, 2001). These counter-examples seem to suggest that, at most, counterfactual dependence may, in many cases, be sufficient for causation, however it is not necessary.

determination examples reveal production without counterfactual dependence, whereas omission and double-prevention examples reveal counterfactual dependence without production. In what follows, I argue that examples of omission and double-prevention are underpinned by causation as production and that counterfactual dependence is only symptomatic and not constitutive of causation, at the level of a metaphysical analysis. Nonetheless, it remains the case that a counterfactual analysis of true causal claims has a practical role to play in explanation and normative claims.

A potential case of causation by omission is provided by the claim: 'Amelia's failure to water the plant caused it to die'. This seems a clear case of causation. If it is then Amelia's failure gives rise to an effect, namely the plant's dying. Under a counterfactual analysis, the truthmaker for the claim is the counterfactual state of affairs, or possible world, in which Amelia does not fail to water the plant and the plant does not die. Conversely, a productive analysis appears to struggle to provide an account of how it is that an omission (as the lack of something), in standing as a cause, can generate or bring about something else.

In subscribing to a productive account of causation I would deny that omissions are causes. However, this is not to say that omissions are not causally *relevant*; they are relevant because they are explanatory. Omissions may appear to be causes, but this is only on the assumption that causal claims wear their ontological implications on their sleeves. In other words, that they indicate what it is about reality that makes a causal claim true. Since 'Amelia's failure' is quantified over in the causal claim, an assumption can be made that 'Amelia's failure' is an existent particular and, as such, has the potential to be causally effective. In the case of causal claims, I think there is good reason to reject the assumption that the grammatical structure of those claims mirrors the metaphysical reality. On the grounds of ontological parsimony, we should avoid positing omissions, as an addition to our ontology, if an alternative explanation can be given, and I argue here that a productive analysis provides such an explanation.

Causation is a feature of concrete existence, or existence in spacetime; it is not something that obtains between abstract entities. Under a productive account a cause brings its effect into (concrete) existence and so both cause and effect are spatiotemporally locatable. Incidentally, this is equally true in the case of thoughts, beliefs and intentions. Laura's belief (at 12 noon on 15th July) that the train would leave at 12:05 caused her to run to the station. In contrast, Amelia's failure (the ostensive cause identified in the causal claim) is not something that exists concretely, and so cannot be causally efficacious in bringing about the death of the plant. For the productivist, the truthmakers for the state of affairs that brought about the death of the plant include a variety of physiological factors connected with the plant, such as the evaporation of water from the soil and the leaves of the plant (Mumford and Anjum, 2011, p. 148). The causal claim, where true, is not made true by the causal efficacy of Amelia's failure.

Nonetheless, there is a true counterfactual: if Amelia had not failed to water the plant, the plant would not have died. The truth of the counterfactual is *symptomatic* of causation occurring in the actual world, but it is not *constitutive* of the causation. It is not constitutive because it is not necessary, as cases of over-determination reveal. Forgetful Amelia might have an evil twin, Lily, who poisons the plant and in this case the counterfactual is untrue and the plant dies anyway.

As Hall (2004) intimates, cases of double-prevention also appear to provide difficulties for a productive account, whereas a counterfactual analysis seems more intuitive. The case discussed by Hall involves two fighter pilots, Suzy and Billy, on a bombing mission. Billy acts as Suzy's escort and he intercepts, and shoots down, an enemy plane, such that Suzy's mission can continue on uninterrupted, with the consequence that she successfully bombs her target. Billy's firing prevents the occurrence of another event (the destruction of Suzy's plane) which, had it occurred, would have prevented Suzy's bombing of the target. The true counterfactual claim (if Billy had not fired then Suzy's target would not have been bombed) supports the intuition that Billy's firing is a cause of the target being successfully bombed. Hall considers that such an example presents difficulties for a production account since there is no direct physical (spatiotemporally continuous) connection between the cause (considered as Billy's firing) and the effect (the bombing of the target).

I disagree. In this case, there is a good reason to think that Billy's action is *not* a cause, despite the true counterfactual claim, and this is suggested by a further example that Hall himself provides. In this slightly altered example, Hall (2004, p.12) describes a scenario in which the event structure is causally identical to the previous example yet Billy's firing turns out *not* to be a cause, under a counterfactual analysis. Hall's assertion that the two situations are causally identical is based on what he refers to as the 'Intrinsicness' thesis: 'The causal structure of a process is determined by its intrinsic, non-causal character (together with the laws)' (p. 1). Any two sets of events which share a causal structure, S, result in the generation of the same effect, *e* (p. 12).

In this modified example the enemy plane is present but is under no instructions to shoot anyone and, had Billy not fired, it would have received instructions to return to base immediately. In this case, under a counterfactual analysis, since the enemy plane would not have shot Suzy's plane, Billy's action turns out *not* to be a cause of the bombing. In situations where a causally identical event structure obtains, a counterfactual analysis can provide a conflicting account of the cause. In contrast, under both these (double-prevention) scenarios, a production account does assign the *same* cause. Namely, it is Suzy's bombing that *brings about* the destruction of the target, and so it is Suzy's bombing that stands as the cause.

Contra Hall, in the case of double prevention, a production account *is* able to provide an account of the cause and, furthermore, one that is consistent across scenarios that are structured in a causally identical manner. It is just that it allocates a *different* cause, in the first scenario, to that suggested by the true counterfactual claim. If two situations are structured as to be causally identical, in the manner proposed by Hall, then what is designated as the cause should always come out as the same under an adequate account of causation; but this is not the case under a counterfactual account.

This highlights something important about the difference between counterfactual and productive analyses of causal situations. In the following section I argue that the difference is this: a productive analysis of causation addresses the *metaphysics* of causation, whereas a counterfactual analysis concerns the *epistemology* of causation.

7.4.3 Metaphysics Versus the Epistemology of Causation

As argued above, counterfactual analysis is certainly symptomatic of causation going on. This is reflected in the fact that causal situations can be described in terms of, or represented by, counterfactual causal claims of the form 'If *C* had not occurred, then *E* would not have obtained', where *C* and *E* stand in a relation of cause and effect. Counterfactual causal claims have an important role to play in our accounting for, and representing, the causal nature of reality and this accounts for the intuitive force of a counterfactual analysis of causation.

Counterfactual causal claims can be distinguished into 'token-level' and 'type-level' claims. Token-level claims have an important role to play in description, explanation, grounds for decisions, and general normative claims (such as the assignment of responsibility or blame). In the first double-prevention scenario, where Billy's actions in taking down the enemy plane facilitated the ultimate success of Suzy's bombing mission, Billy's firing is designated a cause because it is *explanatorily relevant* to the successful bombing of the target (the effect). There is an intuitive sense in which Billy contributed to the success of the outcome and so should be accorded some recognition. In the second case, although the events that occur are causally related in the same way, Billy's firing is not explanatorily relevant (Suzy's mission would have been successful anyway) and so the same action is *not* designated as a cause, even though the two scenarios share the same causal structure.

This is not the case under a productive analysis. Within both scenarios what counts as the cause is the *same* since the cause is that which brings the effect into being. A productive account allocates the descriptor 'cause' to that which is *metaphysically* relevant to the effect, rather than that which is simply explanatorily relevant. Causes are metaphysically relevant to their effects in that they bring their effects into existence. Any adequate *metaphysical* account of causation should be able to identify the same event as the cause in all situations that possess an identical causal structure; yet it is only the productive analysis of causation that is able to do this. The difference between a productive and a counterfactual analysis of causation is that a productive analysis targets the metaphysical core of causation, rather than its epistemological aspects.

The fact that the same action is not designated as a cause under a counterfactual analysis reflects that the assignment of causes in token-level causal claims is often not entirely objective, but can reflect subjective concerns and motivations. This also explains the motivation, under a counterfactual account, to designate omissions as causes in token causal claims. Our assignment of responsibility for the death of the plant to Amelia's omission underpins the sense in which the counterfactual (had Amelia watered the plant, it would not have died) is true. Although omissions are not causally efficacious, they *are* causally relevant because they are explanatory.

The subjectivity in the assignment of causes in token-level causal claims is brought out in Hüttemann's (2013) example of a drunken individual driving in muddy, slippery conditions. Depending upon the motivation of the individual making the claim, the effect (the collision with a bollard) can be attributed to alternative causes (the drunkenness of the driver or the mud on the road). A token-level causal claim can highlight one of many contributory causes depending upon the social, moral or cultural context. Different people may make different causal attributions, for example, attributing situational or contextual factors rather than personality traits, in the same situation. At the level of a metaphysical analysis, however, there is a single (complex) cause of the accident, and this is the resultant sum of all contributing factors that *bring about* the effect, for example, the location of the bollard, the angle of the front wheels, the speed of the vehicle and the increased inertia from the slippery road. These may or may not be identified within a given causal claim due to their lack of utility, or even our ignorance as to their role (such as the increased inertia contributed by worn tyres).

Counterfactual analysis, as symptomatic of causation, also has a role to play in the generation of type-level causal claims. These relate properties or kinds, and include claims such as 'smoking causes cancer', or 'the over-consumption of calories causes obesity'. Type-level counterfactual claims (such as, 'If no-one smoked then incidences of lung cancer would be lower') have an important role to play in both prediction and the formulation of causal laws, or laws of nature.

In conclusion, cases of over-determination and pre-emption reveal that there can be cases of causation in the absence of counterfactual dependence. In these cases, a productive account is sufficient to account for the causal situation. In cases involving omission and double-prevention, that reveal counterfactual dependence, the counterfactual claims are true because there is causation going on for which an account in terms of production can be given. This supports a view under which counterfactual dependence is symptomatic, but not constitutive, of causation going on in the world. Counterfactual analysis concerns the *epistemology* of causation. It is employed in our representation, modelling or description of causal situations and this accounts for its greater intuitive appeal in certain situations, as well as the vital role that it plays in our concept of causation. However, it is only a productive account of causation that gets to the *metaphysical* root of causation, as it is, objectively, in the world.

7.4.4 The Benefits of a Productive Account of Causation

In this section I first argue that a realist, productive account of causation aligns naturally with the ontology for presentism being offered within this thesis. I also argue that, under a productive account, causation is *not* fundamentally a relation. This provides a further benefit for a presentist account in view of the existence-entailing nature of external relations.

Causation is closely connected with change. If something changes its intrinsic properties, we normally wish to identify a cause for the change. Under the proposed ontology for presentism, real, metaphysical change is primitive (§ 5.9.2)[155] and, along with persistence, is exemplified in the present as one of the

[155] By describing real, metaphysical change as primitive I mean that it is explicable only in terms of existence, and is reflected in the nature of the present.

two objective correlates of tense. Since real change (Def_{RC}) is defined in terms of objective creation and annihilation (§ 5.8), the close connection between causation and change suggests that a compatible model of causation is one that sees causation as involving production, as a bringing into existence.

Hall (2004, §1) describes the production concept of causation as a 'relation' between events; however, I deny that this is the case. Under a production view of causation, causation is not *fundamentally* a relation between distinct entities. Under a production account, a cause brings its effect into being, consequently a cause is existentially prior to its effect. There is therefore no necessary *relation* between cause and effect, in the sense of a co-existence; rather there is, what Ingthorssen describes as, a '*one-sided existential dependence* between cause and effect' (Ingthorsson, 2002, p.8).

If causation were fundamentally a relation between events then, on the grounds that relations imply the existence of their relata, cause and effect would always coexist, and this is not necessarily the case. There are certainly cases where causes and effects do coexist and these are generally situations where the cause not only brings the effect into being but it also sustains, or maintains, it. Kant's cushion is a paradigmatic example of this. For as long as the ball remains on the cushion the gravitational mass of the ball (the cause) coexists with the indentation in the cushion (the effect). Similarly, the rotation of the fan blades (the cause) and the movement of the surrounding air (the effect) coexist. The coexistence of cause and effect in these examples is not a cross-time relation and so presents no difficulties for the presentist.

However, in other situations this is not the case, rather the cause ceases to exist at the point the effect comes into being. In the example of the kicking of a ball and its flight towards the goal, the cause (the kick) ceases at the point at which the effect (the flight of the ball) comes into existence. Similarly, the pressing of the trigger (cause) and the firing of the bullet (effect), the burning of the fuse (cause) and the explosion of the bomb (effect), and so on. In these, and many other, cases the cause and the effect do not coexist and so do not stand in a relation. What is fundamental to causation under a productive account, and in each of the examples given, is that the cause produces the effect, or brings the effect into being. That cause and effect may, or may not, coexist is non-essential to causation.

The idea that causation *is* a relation garners support from the fact that causal situations can be described, or represented, in the form of a causal claim in which two events stand in the relation of cause and effect. Drawing a metaphysical conclusion from this as to the existence of a relation between the entities confounds the epistemological aspects of causation with a metaphysical analysis. Under a productive account of causation, causation is not (metaphysically speaking) a relation and, if it is not a relation, cross-time causal claims do not imply the existence of previously existent relata.

For these reasons a productive account of causation appears best suited to the model of presentism proposed. In developing a productive account there are, however, two approaches that one might take. The first, which has achieved increasing popularity in recent years, is to ground causation in dispositional properties, construed as real (causally effective) powers to bring about certain effects (e.g. Ellis, 2001; Molnar, 2003; Groff, 2008; Mumford and Anjum, 2011; Heil, 2012). The second approach is to view causation as a process as do, for example, Salmon (1984, 1994, 1997), Dowe (1992, 2000) and Ingthorsson (2002, p.14). There is an overlap between the two, though, in that those advocating causal dispositionalism tend to talk in terms of causal processes, despite not being committed to a process ontology.[156] As productive accounts, both approaches also have in common the Aristotelian view that connects causation with a coming into being: 'everything that comes to be comes to be by the agency of something and from something and comes to be something' (*Metaphysics*, Book 7, Part 7, 1032a).

[156] Here I cite some examples. 'The most fundamental kinds of things in nature all seem to be both active and reactive. They have powers both to act and to interact with things of other kinds, and to be agents in a variety of causal processes' (Ellis 1999 p. 19). 'Ball *a* first meets *b* at time t_α, let us say, and they go their separate ways, after some interval, at time t_ω. For as long as they are together, squashing into each other and then springing apart, causation is going on, according to our account. There is a *process*, which takes time, but this *causal process* has not begun until t_α and has not ended until t_ω.' (Mumford & Anjum 2011, p. 109).

Since the ontology proposed within this thesis includes the category of pure process, it might be considered that a process account of causation should be the more compatible approach. In the following section I review certain problems that arise with process accounts of causation and conclude that a suitable account combines elements from both causal process theories and dispositional accounts of causation. I outline such an account in § 7.5.

7.4.5 Process Accounts of Causation

Causal process theories originate in the approach of Salmon's (1984) 'Mark Transmission' theory, under which causal processes are ontologically distinguished from 'pseudo-processes' in that the former transmit their own structure ('mark transmission'). Following criticism (Kitcher, 1989 and Dowe, 1992) that his mark transmission theory collapses into mere counterfactual dependence, Salmon (1994, 1997) subsequently adopted a modified form of Dowe's (1992, 2000) Conserved Quantity Theory.

Central to the accounts of both Salmon and Dowe are the concepts of 'causal process' and 'casual interaction', defined by Dowe (2000, p.90) as follows:

> CQ1: A *causal process* is a world line of an object that possesses a conserved quantity
>
> CQ2: A *causal interaction* is an interaction of world lines that involves an exchange of a conserved quantity[157]

Froeyman (2012)[158] argues that process theories of causation, as principally developed by Salmon and Dowe, fail to provide an original account of causation that offers anything, ontologically, over and above a reductive, physicalist account, such as that proposed by Fair (1979). Fair argues that any instance of causation reduces to a transfer of energy-momentum from the entities that comprise the cause to those that constitute the effect: 'the causal connection is a physical relation of energy-momentum transference' (p. 229).

[157] Conserved quantities include, for example, momentum or mass-energy.
[158] Kitcher (1989) also argues along similar lines.

Given that causal processes are defined, by both Salmon and Dowe, as the world-lines of *objects*, Froeyman argues that it is surely objects that are exchanging the conserved quantities. The concept of causal process is thereby ontologically redundant (p. 538), and this leaves the concept of 'causal interaction' to do the ontological work within the theory. Since interaction is cashed out in terms of the exchange of a conserved quantity, for Froeyman, there is nothing of ontological merit to causal process theory that is not already available within Fair's transference theory.

Froeyman garners support by noting that both Salmon and Dowe were heavily influenced by Russell's concept of 'causal lines' in formulating their notion of a causal process. Froeyman regards this as a methodological error since, for Russell, causal line is an *epistemological device* and not an ontological concept. Russell employs the concept of a 'causal line' to connect the basic entities in his ontology: discrete events, time and regularities. In particular, causal lines provide Russell with a means of accounting for the persistence of ordinary objects in time: 'A "causal line", as I wish to define the term, is a temporal series of events so related that, given some of them, something can be inferred about the others' (Russell, 1948, p.477).

Further support for Froeyman's claim comes from Dowe's employment of causal process to account for 'immanent causation', which Dowe sees as an additional benefit of his process theory of causation. For Dowe, immanent causation is the sense of causation implied by stating that an object's inertia *causes* its continuing motion, and he sees this as an aspect of causation that has not been properly addressed (2000, p. 52). According to Froeyman there are two possible ways of unpacking Dowe's notion of immanent causation. First, it might mean that the movement of an object at time t is the cause of its movement at a later time, t'; if so, then immanent causation seems simply to be a restatement of Russell's causal theory of identity over time, which connects an object at one time to the same object at a later time. If Dowe's concept of causal process explains immanent causation, in this sense, it is merely a disguised version of Russell's causal line mechanism. Since the latter is merely an epistemological device, then the true (ontological) nature of causation remains obscure and the explanation of immanent causation, under Dowe's theory, provides no additional benefit.

Alternatively, Froeyman suggests, immanent causation might be understood as stating that the inertia of the spaceship at t is the cause of its movement *at t*. In this case, Froeyman argues, immanent causation is 'more tautological than causal. Inertia is just another (scientific) term for movement' (p. 535). The inertia of an object at t just is, by definition, its continuing motion at t and so there can be no external (and so causal) relation between inertia at t and continuing motion at t. For this reason, Froeyman describes immanent causation as an 'empty notion' (p. 535). If the notion of immanent causation is empty, then the concept of causal process does no additional ontological work under Dowe's account.

I agree with Froeyman that the concept of causal process is ontologically redundant in both Salmon's and Dowe's accounts, but there is a further reason why this is the case. Under Salmon's and Dowe's accounts the concept of causal process (like that of Russell's causal line) is a mechanism to secure the persistence over time of discrete entities (namely objects). This implies that processes, rather than being ontologically fundamental, are derivative of more fundamental entities, namely objects and time. Under a more rigorously process-ontological account (such as that of Seibt, and the account presented here), processes are considered to be ontologically fundamental and, as such, are intrinsically persistent (Chapter 6, § 6.3.3). Processes exemplify continuity and an essential on-going-ness. Consequently, the persistence of processes requires no reference to an external time, under the ontology proposed within this thesis. This means the notion of world-lines, employed to provide for continuing identity through time, is redundant and consequently so is the concept of causal process, as it is defined within causal process theories.

A further indication that the ontology underlying causal process theory is not sufficiently processual is provided by the fact that Dowe's theory is motivated by a need to account for inertia (through 'immanent causation'). In line with Newton's First Law, inertial motion, as continuing motion, is a default mode of matter and, as such, requires no *causal* explanation. Equally, remaining at rest over time (or persistence) is also prescribed by Newton's First Law as a default state of matter. These default states of matter are represented as defining features of the category of pure process within the ontology proposed in Chapter 6. Since pure processes are ontologically primitive, under a rigorous process account neither inertial motion nor persistence require further explanation.

Froeyman's conclusion, that the ontological core of causation, under causal process theories, is provided solely by the *interaction* of processes appears justified. There is no doubt that causal situations *involve* processes (the motion of the brick towards the window, the movement of one billiard ball towards another) but this does not mean that accounting for causation requires reference to a unique species of process, a 'causal process'. Nonetheless, Froeyman's arguments do expose the key feature of causal process theories that is correct. This is that causation requires interaction. The brick has to interact with the window by hitting it, thereby causing it to break, in order that the situation counts as causal. If it merely passes it by there is no cause-effect dependence.

Under causal process theories causal interaction is defined as an intersection of world-lines involving the exchange of a conserved quantity. This concept of causal interaction is not adequate for the account to be provided here, for three reasons. First, causal interaction, so defined, has an implicit dependence on a substantival account of time in order to individuate the point of intersection of the relevant world-lines. This makes it unsuitable for a successful presentist account, which requires a reductionist account of spacetime. The reasons for this have been given in previous chapters.[159]

Second, seeing causation simply in terms of the transference of conserved, physical quantities appears insufficient to account for the emergence of general

[159] To summarise, it is argued (§ 5.5) that a successful presentist account requires an internalisation of the objective correlates of tense; this commits the presentist to a reductionist, or relational, account of B-series time. In Chapter 2, I argue, from the problem of time in Quantum Gravity, that a reductionist account of spacetime is more compatible with our best physical theories.

causal laws. A reductionist account is not nuanced enough to explicate the difference between ‘throwing a brick at the vase causes it to smash’ and ‘smoking causes lung cancer’. In the former case, a physical transference account of causation is explanatorily sufficient to explain the shattering of the glass vase. Kinetic energy from the motion of the brick is transferred to the vase and is sufficient to break the bonds comprising the crystal structure. Individual pieces of the glass subsequently fly through the air as a consequence of the transferred energy-momentum. However, this explanatory sufficiency does not extend to the case of a causal law such as ‘smoking causes lung cancer’.

That smoking causes lung cancer is explained by the ability of certain chemicals in cigarette smoke (e.g., benzopyrene) to facilitate gene mutations. Gene mutations involve the substitution of base pairs in segments of DNA in cells (e.g., cytosine for adenine). Such substitutions can, at the level of molecular interactions, be explained in terms of the exchange of energy between molecules, through the breaking and creation of chemical bonds. However, a causal explanation of gene mutations at the level of energy transference is unable to account for the fact that mutations can be beneficial or malignant, depending upon where in the genetic code the mutation occurs. The same physical transference mechanism can cause both beneficial mutations (such as HIV resistance) and harmful ones (such as lung cancer). In the case of complex physical, biological, economic and social systems, to which general causal laws apply, a theory of causation sufficient to account for such laws has to provide a unified explanation of causation for both emergent and fundamental phenomena.

There is a third reason why causal interaction has to be more than an exchange of conserved quantities. Although the transfer, or exchange, of conserved quantities is indicative of causation going on at the fundamental physical level, reducing causation to this fails to account for the sense in which causation involves novel production. The exchange, or passing around, of energy-momentum appears to suggest that both cause and effect are already in existence. This is at odds with the productive account of causation that is being sought, an account under which causes generate, or bring into being, their effects.

7.5 A Process-Dispositional Account of Causation

Causal process theories highlight the importance of both processes and the interaction of processes in accounting for causation. It is noted, however, that several aspects of causal process theory render it unsuitable for modelling causation under the proposed presentist account. In this section, I propose an account that combines elements from both causal process theories and dispositional accounts of causation. Prior to describing the account, I provide an overview of the nature and role of dispositions in accounts of causation.

7.5.1 The Nature and Role of Dispositions

Recent neo-Aristotelian developments in analytical metaphysics have seen a trend towards realism about causal powers through the employment of dispositional properties. Such causal-dispositionalist models consider dispositional properties as *real* properties of objects (e.g. Ellis, 2001) that reference the active, or dynamic, nature of their bearers: they are dispositions-to-*do* and can exist unmanifested. The causal role of dispositional properties is essential to them: the identity of a property is constituted by its exercising a certain causal (and so nomological) role. The power of salt to melt ice, for example, is a dispositional property. There are, though, differences within the accounts as to the extension of the concept *dispositional property*.[160] Despite this, what the various accounts have in common is that dispositional properties, however conceived, are *real* to the extent that they are causally efficacious.

There are two advantages to utilising dispositional properties within a presentist account of causation. Firstly, dispositional properties are dynamic: they imply potentiality and, in doing so, suggest that the future is open and yet to occur. They can thereby provide a ground for objective becoming and real,

[160] Some, such as Ellis (2001), Bird (2007), Mumford and Anjum (2011) and Heil (2012, pp. 59-62), deny that there are any truly categorical properties and take a pan-dispositionalist stance under which *all* properties are construed dispositionally, as clusters of causal powers. For example, charge is the power to create an electromagnetic field.

metaphysical change. The second is that powers are not necessarily reducible to forces or conserved quantities. They can be macroscopic. This permits a unified ontological basis across the sciences operating at different levels of reality (from physical, chemical and biological to social and economic). This also means that, unlike under causal process theory, there is scope for accounting for the emergence of general laws and the differences between them.

In the account that follows, I adopt the view that dispositional properties (e.g. fragility, brittleness, solubility) are intrinsic, causally efficacious powers possessed by concrete entities. These powers can include both simple powers (in the case of charge, the power to repel) and complex, or macroscopic, powers (in the case of financial markets, the power to create wealth) where the latter are not necessarily reducible to the former.

There is also a need to distinguish dispositional properties from their associated manifestations. Motivated by Ryle's (1949) notion of multi-track dispositions, Kistler (2012) notes that a given power can be the causal basis for more than one manifestation. For example, elasticity is a single, intrinsic, physically grounded power that can be associated with several manifestations, such as 'contracting after being stretched', 'expand after being compressed' or having 'bounced on sudden impact' (Ryle, 1949, p.113). Whereas powerful properties are intrinsic their manifestations are relational (and depend upon external circumstances).

The terminology I shall adopt is to refer to the intrinsic causal power, or disposition, as a *powerful property* and the various expressions of that powerful property as *manifestations*. In the next section, I outline the main elements of a process-dispositional account of causation.

7.5.2 Accounting for Causation

Dispositional accounts of causation standardly assume a substance-based metaphysics. The ontology proposed in the previous chapter comprises a hierarchy with concrete substance and powerful properties occupying the top tier, and the mutually inter-dependent categories of pure process and interaction event comprising the second tier. As described in § 6.7.2, everyday, substantial objects are modelled as a hierarchical complex of pure processes and interaction events (at the ontological level); their exact constitution depends upon the extent to which they manifest a more continuant-like nature (such as an unchanging rock) or are more occurrent-like (e.g., explosions). Such complexes may also be conceived of as possessing powerful properties.[161]

Rivers, consist of material substance (the energy-momentum of the water molecules that comprise it) and this material substance exists as both pure processes (such as its flow, or continual motion) and as interaction events (e.g., interactions between water molecules give rise to frictional drag and turbulent flow, interactions between the water and the river bank give rise to erosion). Rivers, as pure process-interaction complexes, also possess powerful properties, such as a capacity to erode their banks. Similarly, typhoons have the ability to flatten buildings and financial markets reveal a disposition to collapse. In the case of complex entities (such as financial markets) their powerful properties are not necessarily reducible to a physical basis.

Powerful properties can also be associated with material substance at the fundamental, physical level. Light, is an archetypal pure process, and has the power to transmit energy-momentum. When light interacts with the surface of a metal plate it can transmit a photon of energy which is captured by an electron at the surface and this results in the electron being emitted (the 'photoelectric effect').

Under the account proposed, causation occurs when pure processes (characterised by their powerful properties) interact and novel production results. It will be recalled, from § 6.7, that the interaction of pure processes is an *interaction event*. Interaction events are also defined as points at which new pure processes are created or annihilated. This account is thereby a production account of causation: any causal situation requires interaction (where interaction is necessary and sufficient for causation to occur) and involves novel production. In this manner causation is connected with real, metaphysical

[161] It should be noted that, although we predicate (powerful) properties of both processes and events, it is the underlying concrete substance that is the possessor of such powerful properties, and the truthmaker for true claims about propertied process and event complexes.

change - the ontological category of interaction event reflects the primitive nature of real, metaphysical change (§ 6.7).

Consider the example of the thrown brick that causes the window to shatter. The brick in motion is a pure process (inertial motion, in exemplifying the continuation of some functional dynamic, is a model example of the category of pure process, § 6.7). The brick in motion also possesses momentum, in virtue of which it has a powerful property: the power to fracture glass. The window, as a complex entity, is a macroscopic pure process (it exemplifies the category feature of persistence, as continuing existence). The interaction of the brick in motion (pure process) with the window (pure process) is a causal situation that leads to the shattering of the window. The glass window has a powerful property, fragility, a disposition that manifests in shattering, upon the transfer of momentum from the flying brick. This interaction event is also the point at which a new pure processes are created and existing processes are annihilated. The scattering of pieces of shattered glass are new pure processes with their own powerful properties, some of which are different from those of the window; their sharp edges have a disposition to cut, for example. A further pure process may also be created if, for example, a small piece of brick had broken off during impact. Pure processes are also annihilated in the interaction event. In this case the original, participating pure processes: the persisting window and the inertial, forward motion of the brick. The situation, as causal, may also described by a true counterfactual: had the brick not interacted with the window, the window would not have shattered.

I share the view of Mumford and Anjum (2011, Chapter 2) that in a given interaction situation all causally relevant powerful properties (those relevant to the given manifestation-type, both contributory and counter-vailing powers) combine in an additive, and lawful, fashion to produce a manifestation-type once a threshold level is reached; it is at this point that the effect is triggered. In cases where a single powerful property dominates or in artificial (laboratory-style) situations, where background conditions and minor contributory causal powers are screened out, the connection that exists between a powerful property and its manifestation-type(s) permits the derivation of general causal laws.

The *cause* (metaphysically speaking), in any given token situation, is that which brings the effect into being. A cause therefore comprises the interacting pure processes, together with all their causally relevant powerful properties. This reflects Mill's (1843, pp. 398-399) conception of a 'real' or total cause. Consequently, no (ontological) distinction is to be made between causally relevant powerful properties that dispose towards the effect-type produced and countervailing powerful properties (those that dispose against the effect-type), such as interfering factors. All causally relevant powers (including background conditions) count as part of the metaphysical cause. Nonetheless, our explanations or representations of the situation, through token-level claims, might focus on only certain of the contributory powers, for the reasons discussed in § 7.4.3. For example, the major causal contributor to lung cancer is smoking, however, exposure to both radon and diesel exhaust fumes can also contribute. Conversely, a diet rich in antioxidants and regular exercise are counter-vailing powers that can contribute to preventing lung cancer. Nonetheless, all the causally relevant powers, positive and negative, contribute to the resultant effect though it may only be smoking, as the predominant powerful property, that is referred to in any token causal claim.

This view of the cause (as 'total cause') is not shared by all dispositional accounts. For Mumford and Anjum (2011, pp. 33-34), a cause is the sum total of just those powers that dispose *towards* the given effect, *E*. Countervailing powers (those that dispose *away* from given effect) are not the cause of *E*, though Mumford and Anjum accept that they could still be 'a cause of *E* happening in a certain way' (p. 34). They illustrate this with the example of a life-support machine that postpones the death of a fatally wounded person. Since the life-support machine disposes towards continuing life it cannot, for them, count as part of the cause of the individual's eventual demise.

I am not sure that this example justifies the exclusion of countervailing powers from a metaphysical account of cause. The life-support machine has similar causally relevant powers to those of a fully-functioning heart and lungs, which also dispose towards maintaining the life of an individual. In a situation where an individual is shot, it is the continued pumping of the heart that causally contributes towards the person bleeding to death. As such it counts as part of the cause, construed as the sum of *all* contributory powerful properties, even though it disposes towards continued existence. The stance taken by Mumford and Anjum also appears at odds with their vector model of causal situations (pp. 28-39). Under this all interacting causal powers present (both contributory and countervailing) are represented as vectors, with the resultant vector used to explain the nature of the effect obtained. As such it seems difficult to understand why the resultant vector, as the sum total of all powerful properties present, should not be equated with the cause, as that which produces the effect. Nonetheless, elsewhere (p. 32) they accept that there can be no ontological distinction between causes and background conditions since, metaphysically, they all contribute.

7.5.3 Conclusion

In this section I have described a productive account of causation that aligns with an ontology, proposed in Chapter 6, suitable for an account of presentism that is compatible with our best theories of physics. Under the productive account of causation proposed, causation is not fundamentally a relation (§ 7.4.4). Consequently, cross-time causal claims do not imply the existence of previously existing relata. Yesterday's storm does not stand in an existence-entailing relation with today's flood: it is the cause of 'today's flood' in that it brought the flood into being. Progenitive cross-time relations, such as *is the grand-daughter of* (encountered in the case of Emily and Edna, § 7.2.1), can also be reduced to causal production (as suggested by Bourne, 2006, p.96) in order to remove their existence-entailing implications. The truthmakers for claims that involve progenitive relations are facts about the causal origin of the presently existing entity (e.g. Emily).

In the remaining section I discuss the issue of spatiotemporal CTR claims and concede that the ontological model proposed in this thesis provides no advantage over existing presentist strategies.

7.6 Dealing with Spatiotemporal CTR

Dealing with cross-time spatiotemporal relations within the scope of the proposed model presents particular problems. I first explain why two of the strategies discussed in the previous sections do not work, before considering two remaining options that are available.

As noted in § 7.3.1, Sider (1999) suggests, on behalf of the presentist, that cross-time relations should be construed as internal relations as far as possible. This option, however, does not seem possible for spatiotemporal relations under the account proposed here. In § 6.8.2 I argue for a presentist-compatible version of Belkind's Primitive Motion Relationism which replaces events (and so spacetime points) under Belkind's model with the interaction events of the proposed presentist ontology (§ 6.7). As with Belkind's model, the spatiotemporal relation (or interval, ds^2) between interaction events is given by the primitive inertial motion (PUM) that connects the two events. In the case of the simple light clock (Figure 6.3, § 6.8.2) this is the motion of light between the two opposing mirrors. In general, for a spatiotemporal relation to obtain between any two events there must be some common motion that connects them. Spatiotemporal intervals are therefore unit intervals of the motion that connects events, or spacetime points. This means that under the proposed presentist account spatiotemporal relations are genuine, external relations between events that cannot be erased away. There is, ontologically, something over and above the events themselves that relates them, namely, the inertial motion that connects them.

A second possibility presents itself. I have argued (§ 7.4.4) that causation, rather than being a relation between events, is, under a production account of causation, a matter of existential dependence. This suggests that a potential strategy is to reduce spatiotemporal relations to a causal dependence between spacetime points. Ostensive support for such a strategy comes from the fact that, under the proposed ontology, spacetime points are necessarily causal. This is because spacetime points are 'interaction events'[162] and an interaction event (as defined in §6.7) is 'an interaction between two or more pure processes and is a point of novel creation or annihilation of pure processes'. Under the productive model of causation developed in §7.5.2, 'causation occurs when pure processes (characterised by their powerful properties) interact and novel production results'. Since causation requires interaction and involves production, interaction events are essentially causal in nature.

Despite this, the (spatiotemporal) relation between spacetime points cannot be reduced to a matter of causal dependence, for two reasons. The first reason is that the spatiotemporal relation between two events has a quantitative aspect to it that is not captured simply by causal dependence. Suppose event A is the emission of light from a distant star, five light-years away. As an interaction event this is a spacetime point. Event B is the interaction of the light signal with a telescope on earth, and is a second spacetime point. Event A causes event B (in the sense of bringing it about) and the two events are spatiotemporally related (the temporal component of which equates to 5 years). However, the causal dependence of B on A is insufficient to account for this spatiotemporal relation. In particular, it cannot account for the possible world where the causal dependence between the events is identical but the spatiotemporal relation between them has a temporal component of 4 years. This is not surprising given the explanation above for why spatiotemporal relations are not internal relations. The spatiotemporal interval is provided by the inertial motion that connects the two events and this is something over and above their causal dependence. In the first case the motion is characterised by 5 unit intervals of motion, in the second case it is only 4 unit intervals.

The second reason why spatiotemporal relations cannot be reduced to a matter of causal dependence is that events can be spatiotemporally related without

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[162] Events, under Belkind's (2012) model, are spacetime points and in § 6.8.1 I argue for a structural alignment between Belkind's 'events' (defined as intersections between primitive uniform motions, PUMs) and 'interaction events', under the proposed ontology. On the basis that the argument for this structural alignment is sound, 'interaction events' are spacetime points.

there being any causal dependence between them. For example, there is a spatiotemporal relation between the starting of a fire on 2 September 1666 in the baker's shop on Pudding Lane and the publication of Newton's *Principia Mathematica* on 5 July 1687, yet there is no (obvious) causal dependence. It is useful to clarify, at this point, how the proposed model does account for the spatiotemporal interval between these two events.

The spatiotemporal interval between the fire event and the publication event is given by the primitive motion that connected them. In this case, that primitive motion is a combination of the rotation of the earth and its orbit around the sun.[163] Under the ontology proposed, the interaction event that is the fire in Pudding Lane consists in the interaction of a number of pure processes – the falling embers from the oven, an adjacent pile of timber (which, as an enduring continuant, is also a pure process § 6.7.2) and the prevailing easterly wind. An additional, contributory process is the motion of the earth and this gives rise to the datable nature of the event. As noted in § 2.5, assigning a time (and equally a date) to an event requires reference to the motion of a standard physical system, or clock, and the motion of the earth provides the mechanism for doing this. The second event, the publication of Newton's *Principia*, is also an interaction event that involves a number of pure processes, one of which includes the relative motion of the earth. The motion that connects both events, and so provides the spatiotemporal interval between them, is the continuing motion of the earth in its path around the sun.[164]

The problem for the presentist is that these two events, the fire event and the publication event, no longer exist and neither does the spatiotemporal relation between them, i.e., the primitive motion that connected them. In the case of

[163] It might be objected here that the motions to which I appeal are not inertial. The rotational motion of the earth is not inertial, and the orbital motion of the earth around the sun is only partially inertial. The primitive motions (PUMs), upon which Belkind's derivation of Minkowski spacetime are based, are primitive *inertial* motions, and it is these that constitute the spatiotemporal interval between events. However, Minkowski spacetime is devoid of matter and so represents a limiting case of the spacetime of our substantial universe. As discussed in § 6.8, I believe that Belkind's model can ultimately be extended to the spacetime of GTR (mass-containing spacetimes) if so, it seems likely that the primitive motions required to underpin the model would be gravitational / accelerated motions.
[164] I refer the reader back to the diagram in § 6.8.3 which illustrates how duration (the spatiotemporal interval) arises between two events.

events that were previously present this means that problematic *spatiotemporal* CTR remain, they cannot be eliminated away in the manner in which ostensibly causal CTR are. This suggests that the only recourse for the presentist is to adopt one of the strategies described previously. On the assumption that the principle of relations is accepted, a reductionist approach that posits presently existing entities as the truthmakers for cross-time relational claims is available. One such account that *is* able to account for the quantitative aspect of spatiotemporal relations is Ingram's (2016) Thisness Presentism (after Adams, 1986).

A thisness is a 'particular, primitive, purely non-qualitative property of an entity' (2016, p. 2869) that comes into being with an entity and continues to exist (although uninstantiated) following the entity's demise. Ingram describes thisness as the property '*being x*' (e.g. 'the property *being Anna*', p. 2869), in order to convey a sense in which it is an 'individual essence' tied to a unique individual.

Ingram utilises Diekemper's (2015) notion of *non-rigid ontological dependence* in order to allow that an entity's thisness is ontologically dependent only upon its *initial* existence (and not its continuing existence) in the following way:

> Necessarily, for any x, x's thisness T exists only if x has existed; the fact that the connection between x and T doesn't always obtain, doesn't undermine the fact that T cannot exist without the initial existence of x […] If there are uninstantiated thisnesses of past entities, then there must have been past entities. (Ingram, 2016, p. 2886)

Non-rigid ontological dependence allows Ingram to avoid the problematic existence-entailing relations that such dependencies normally engender and, thereby, to circumvent problems encountered by other versions of Thisness Presentism. An important feature of thisnesses is that they (presently) instantiate primitive past-tensed properties directly associated with their respective entities. For example, Boudica's thisness exists (uninstantiated) in the present and possesses the higher-order, tensed property *having been the thisness of a fierce woman*. Ingram's commitment to primitive tensed properties reflects Bigelow's (1996) Lucretian Presentism but side-steps the criticism that Lucretian truthmakers fail the 'aboutness' criterion.

One of the additional utilities of the Ingram's Thisness account is that thisnesses also possess metric-tensed properties, and it is this that can be used to account for the quantitative nature of spatiotemporal relations. The property *having been the thisness of a fierce woman* is an example of a property that, once gained, a thisness can never lose, and this reflects the fixed nature of the past. Nevertheless, the metric-tensed properties possessed by thisnesses *can* be gained and lost over time. Ingram (2019, p. 125) provides the example of a property possessed by Marie Curie's thisness: *having been the thisness of the woman that discovered Polonium 119 years ago*. This property has (at the time of writing) already been lost by Marie Curie's thisness and replaced with the property *having been the thisness of the woman that discovered Polonium 122 years ago*. Ingram's version of Thisness Presentism is thereby able to provide the truthmakers for the claim that the publication of Newton's *Principia* Mathematica took place 20 years and 10 months after the start of the fire in a baker's shop on Pudding Lane.

Despite the utility of Ingram's account, the 'nefarious' objection (Tallant and Ingram, 2015) remains: if non-rigid ontological dependence provides sufficient grounds for the truth of any true CTR claim then there is no need for any presently existing surrogate. If the ontological price of presently existing surrogates outweighs the utility to be gained from thisnesses then the only remaining strategy for the presentist is to eschew the need to be ontologically upstanding and deny the requirement to provide truthmakers for true CTR claims.

7.7 Concluding Comments

The aim of this chapter has been to show that the proposed ontology (set out in Chapter 6) can defuse some of the threats to presentism implied by claims involving cross-time relations, if a realist and productive account of causation is adopted. The key role played by an appropriate model of causation is highlighted by the fact that both the standard presentist approaches to CTR (eliminativist and reductionist) struggle to provide a satisfactory account of cross-time causal relations. Nonetheless, it is conceded that spatiotemporal CTR are difficult to accommodate, and this rests in part on their quantitative nature. In the remaining chapter I make the case that the account proposed in this thesis provides scope for accounting for an additional problem that faces the presentist, namely the asymmetry of fixity.

CHAPTER 8 – THE ASYMMETRY OF FIXITY

8.1 Introduction

In the previous chapter I described how a productive, realist account of causation might provide the means for the presentist to circumvent problems associated with cross-time causal relations. Equally problematic is the ostensive symmetry that obtains between past and future: to the extent that neither exist, they are both unreal. This picture is at odds with the intrinsic asymmetry we encounter in the universe and this is where the Growing Block theorist appears to have a significant advantage. A presentist account therefore needs to provide some form of connection between the present and the past, but one that reflects the asymmetry between past and future without engendering undesirable ontological consequences. The aim of this chapter is to show how the proposed, compatibilist, model of presentism is able to account for the asymmetry of fixity in a manner that maintains the presentist commitment that only present entities exist.

In what follows I concur with Diekemper's (2005) argument that the asymmetry of fixity demands an ontological basis. I pursue Craig's (2001b) suggestion that this needs to be grounded in the nature of objective becoming. I describe how objective becoming arises from the nature of the present in virtue of its exemplification of the opposing features of real, metaphysical change and persistence. Although both past and future are unreal, an asymmetry of fixity arises from an ontological dependence between what has been ('the past') and the present, one that does not obtain between the present and what has yet to be ('the future'). This reflects the fact that what no longer exists is fixed and settled. This ontological dependence is asymmetrical.

8.2 Diekemper's Arguments

Diekemper (2005) argues that, as an A-theorist, the presentist maintains a belief in an 'asymmetry of fixity' (p. 223) in that the past is fixed but the future is open and has yet to be determined. This, however, is inconsistent with the ontological symmetry implied by presentism which accords an equal ontological status to both past and future; both are unreal or non-existent:

> But, given the presentist's denial of past existence, she is unable to provide an account of the difference between past and future that also accounts for the difference between present and future. The only ground the presentist can offer for the latter is an ontological one, but then she must withdraw this ground in trying to account for the former difference. Thus she is unable to fully capture the asymmetry. (p. 238)

This issue, he notes, has been inadequately addressed under presentist models, other than that provided by Craig (1991, 2001b) whose arguments he targets. For Craig the asymmetry of fixity is expressed in the notion that 'the past is actualised while the future is merely potential' (1991, p.152); yet, for Craig, this cannot be an *ontological* asymmetry given the equal ontological status of the past and the future. Instead the asymmetry is provided in terms of a causal-temporal asymmetry grounded in an objective temporal becoming:

> The asymmetry between past and future lies not in their ontological status, but in the fact that in the present there are traces only of the past, and this fact is rooted in the impossibility of backwards causation, which is founded, in turn, upon the objective reality of temporal becoming. (Craig, 2001b, p. 34, footnote 10)

After dismissing various strategies, one option that Diekemper considers, on behalf of the presentist, is that present traces (as real) *determine* the past and, as determined, it is thereby fixed. Diekemper's objection here is to reject determinism (both forwards and backwards) on quantum mechanical grounds. He also notes that the presentist cannot allow determinism to work both ways (forward and backwards) since then the potential asymmetry is lost.

In advancing this criticism Diekemper appears to confound fixity and determinism and there is a vital distinction to be made here. Determinism, as Diekemper states, implies that 'given the present state of the universe *S* and a past time t_p, there is only one possible state of the universe at t_p compatible both with the laws of nature and *S*'s being the present state' (p. 229). This he rules out on quantum mechanical grounds because the state of the universe at t_p could be given by two different wavefunctions, either of which might collapse to provide for the present state of the universe; in which case, the present state, *S*, cannot determine the past state of the universe (viz. which wavefunction obtained at t_p).

This argument seems misplaced. For the presentist, the past is fixed not in that it is determined, rather the past is fixed in that it *has occurred*. An example highlights this difference. A radon-222 atom decays by alpha particle emission to a polonium-218 atom. Assume that the present state of the universe, *S*, is given by the present existence of the polonium-218 atom and the alpha particle. A past state of the universe, the one that features the undecayed atom (radon-222), might be described by two different wavefunctions, one of which collapses to give the present state of the universe, *S*. This past state was therefore not determinate. Nonetheless, the undecayed atom is past in the sense that it *has occurred* and was previously a present state of the universe. The sense in which this past state is fixed and settled is that it has previously existed and this state of its *having been* is something separate from its having been a *determinate* state. Quantum mechanics might well be an argument against determinism but it is not an argument against the fixity of the past, as compared with the future.

Diekemper then considers Craig's appeal to the impossibility of backwards causation, in lieu of any alternative account, to provide potential grounds for the asymmetry of fixity. This he also rejects, on the grounds that Craig's favoured account of causation (that of Waterlow, 1974) grounds the unidirectionality of causation on the asymmetry between past and future. Consequently, such arguments cannot be appealed to on pain of circularity.

Diekemper reviews other options open to the presentist but to no avail. This suggests that the underlying problem for the presentist, as an A-theorist, is that: 'any account of temporal continuing and causation that coheres with an A-Theory of time is going to have to presuppose the asymmetry of fixity; in which case, the former cannot ground the latter' (2005, p. 231). Any presentist project to ground the asymmetry of fixity in temporal or causal asymmetries (as Craig attempts) is therefore bound to fail. Against Craig's initial premise, Diekemper concludes that the asymmetry of fixity *must* in some way be ontologically grounded.

Diekemper's arguments have force, in so far as they highlight the apparent impossibility the presentist faces in reconciling the asymmetry of fixity with the equal ontological status of the past and future. The underlying problem appears to be a fundamental conflict between two pillars of (serious) presentism: the commitment to objective becoming (which implies some form of existential asymmetry) and the commitment to the privileged ontological status of the present (which implies that past and future are unreal, and so have the same ontological status). Both Diekemper and Craig concur that the asymmetry of fixity must, in some way, be grounded in the nature of objective becoming. However, Diekemper's arguments suggest that the latter must, in addition, be prior to any temporal and causal asymmetries.

8.3 Sorabji's Circular Time

The need for the asymmetry of objective becoming to be (metaphysically) prior to temporal or causal asymmetries is reinforced by Sorabji's Circular Time scenario (Sorabji, 1988, p. 165), which Diekemper (2005) also discusses.

Sorabji describes a closed-loop temporal world in which time repeats in an endless circle and there is no first nor last event. In this scenario it is equally true that all events are past, and so fixed, and all events are future, and so unfixed. There is a symmetry of both fixity and non-fixity, each direction of time can be seen as both past and future. Diekemper describes such a scenario as follows:

> The planting of a seed leads to the growing of a tree which leads to the shading of the house; events causally related continue in the same way they do in linear time. Of course, since the sequence of events is circular, and there is no detectable first and last event, one could plant a tree tomorrow in order to provide shade for the house yesterday. (1988, p. 232)

The sequence of events is closed and finite in number, this means that it is the same seed that is planted and the same tree that subsequently grows on each circuit of the loop. Despite there being no global asymmetry in fixity I suggest that the presentist would, nonetheless, wish to maintain that there is an objectively moving present. Further, the presentist would maintain that it is this moving present that serves as the ontological ground for the direction of causation or temporal continuing, albeit one that circles round endlessly, as the various events on the circle come into and go out of existence.

A modified example of Sorabji's scenario brings the problem of directionality to the fore even more acutely. Imagine that Sorabji's Circular Time universe is also a perfectly causally symmetrical Gold universe.[165] In this case, we have an acorn (representing the Big Bang-Big Crunch point), indicated by point A in Figure 8.1, which grows into a young tree (point B) and then develops into the fully mature tree (point C, the point of maximal entropy). From this point an identical set of events obtains to reverse the growth of the tree until it assumes the form of a seed once again. This cycle continues ad infinitum.

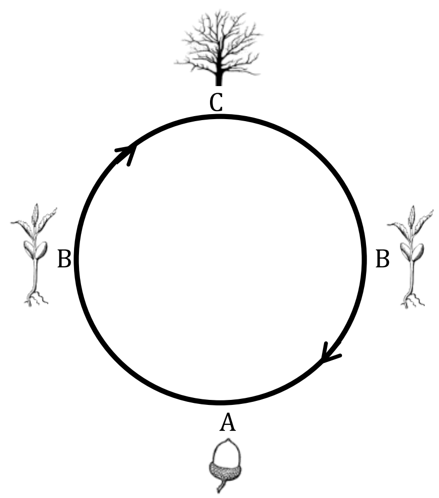

Figure 8.1:

A Hypothetical Sorabji-Gold Universe

[165] After Thomas Gold, a physicist working in the 1960s, who proposed the possibility of 'Big Bang-Big Crunch' cosmological models. These are highly symmetrical universes with a singularity at each end.

Apart from the points A and C (the minimal and maximal entropy states, respectively), for every other point on the evolving cycle it is not possible to tell, from within the given instantaneous state, whether it is evolving from A to C or evolving from C to A. Yet for the presentist, who believes that reality is objectively tensed, there is an objective fact of the matter as to whether the universe at point B is heading towards C ($B_{A\rightarrow C}$) or shrinking back towards A ($B_{C\rightarrow A}$). Newton's God (Chapter 4, § 4.6) could pass judgement on the direction in which the continually evolving present is heading, and so should the presentist. Despite the fact that any event in the universe can be considered equally past or future, there is, for the presentist, an intrinsic directionality in the movement of the present around the circle and it would seem that a presentist model should accommodate this truth.

8.4 Interim Conclusions

I concur with Diekemper that the asymmetry of fixity has to have an *ontological* basis. The only alternative option would appear to be the causal-temporal asymmetry, proposed by Craig. However, as Diekemper's arguments show, this strategy results in circularity where the causal-temporal asymmetry is not independently grounded, but relies instead upon the asymmetry between past and future.

Nonetheless, with Craig, I consider that the only option for an ontological basis of the asymmetry of fixity is to ground this, in some manner, in the nature of objective becoming; more specifically, in the *movement* of the present. It is the dynamic nature of the present that secures the asymmetry of fixity: the fact that the past has occurred and the future has yet to be. For the presentist, an asymmetry exists under Sorabji's scenario despite the absence of a global asymmetry of fixity. This asymmetry arises from an intrinsic directionality within the moving present, and is the sense in which those events immediately 'ahead' of the present are *about to occur* whereas those immediately 'behind' the present *have just occurred*. Objective becoming therefore requires an independent ontological ground and one under which the asymmetry is achieved without compromising the equal ontological status of past and future.

This brings a potential problem into focus. Asymmetry is a property of relations and under the standard Quinean conception of quantification and ontological commitment, relations imply the existence of their relata. Consequently, the asymmetry required also needs to be expressed in a manner that does not incur problematic existence-entailing relations. This is where a process account of presentism can assist in accounting for the asymmetry of fixity. Processes have an unfolding, or developmental aspect to them. Consequently, a process account offers the potential for the movement of the present (and so objective becoming) to be seen in developmental terms as an unfolding of reality in a future-focused direction.

In the following section I provide an account of objective becoming based upon the model for a compatibilist presentism outlined in this thesis. As such, it does not presuppose the asymmetry of fixity, *contra* Diekemper's criticism of Craig's account. In § 8.6, I use this to explain the ontological basis of the asymmetry of fixity.

8.5 An Explication of Objective Becoming

For the presentist, who is also an A-theorist, reality is objectively tensed. This has two aspects to it: the present is continually changing but the present also flows, or moves, with a directionality that points away from what has existed and towards what has yet to come about. These aspects of an objectively dynamic reality are what is referred to by the term 'objective becoming'. In § 5.5 I discussed how it is that tense represents something fundamental about reality. This led to an identification of the objective correlates of tense with both *transience* and *continuity*, and these features of reality were used to inform appropriate formulations of persistence (§ 5.6) and real, metaphysical change (§ 5.8), for the presentist. The present is such that it exemplifies both these two opposing features of reality (§ 5.9.1) and, in what follows, I explain that it is in virtue of these two, opposing, but intimately connected, aspects that the present moves, or flows. It is these features that provide the mechanism for objective becoming.

As explained in § 6.7.2, everyday, propertied substances (such as apples) are hierarchical complexes of the two ontological categories of pure processes and interaction events. These categories reflect the primitive nature of persistence and real change, respectively. Such entities are able both to persist and change in virtue of the mutually dependent nature of these categories (§ 6.7), and so the problem of temporary intrinsics is avoided. The apple, as pure process, is a recurrence of some, apple-generic, functional unity of biological processes and this accounts for its persistence, or continuing existence. The apple complex also consists of interaction events that occur at various points in its continuing existence, such as being picked from a tree. Such interaction events account for real change in the apple. The apple's life unfolds from beginning to end through the interplay of pure processes and interaction events, persistence and real change.

It is this interplay of pure processes (exemplifying persistence) and interaction events (exemplifying real change) within the present that grounds objective becoming. Under Existence Presentism, presence is existence and so the present just is that which exists. That which exists, exists as pure processes, and pure processes continue in existence and so persist. It is the persisting nature of existing entities, therefore, that accounts for the continuity, or flow, of the present. The present continues on in so far as that which exists continues on in existence. Presently existing entities (as pure processes) also interact and such interaction events are points at which new entities (as pure processes) come into existence and existent entities go out of existence, in the present. The occurrence of interaction events accounts for the way in which the present, as that which exists, changes, and this is the extent to which the present exemplifies real, metaphysical change. Thus the present both continually changes and moves forward (or continues on) through the interplay, and mutual dependence, of persistence and real, metaphysical change. It is the combination of these two aspects of the present, to continually change and move forward, that is referred to as objective becoming.

An analogy is helpful to explain how a flow or movement can arise through an interplay of both continuity (persistence) and creation / annihilation (real change). Consider a pixelated worm which consists of a line of 8 individual lights on an LED screen. The forward motion of the worm across the screen is simulated by individual lights sequentially coming on at the front end of the worm and going off in sequence at the rear end. The continuing existence of the worm (its persistence) obtains in virtue of a generic, pixelated-worm functional continuity namely, that there continues to be a line of 8 adjacent pixels that are lit up. Real change occurs with the sequential turning on (a coming into existence) and turning off (a going out of existence) of lights at either end of the worm. It is in virtue of an interplay of persistence and real change that the worm moves in a forward direction across the screen.

Formulating the present in terms of the opposing features of metaphysical change and persistence allows the presentist to *internalise* the objectively dynamic aspects of reality, represented by tense, and avoid the problems of contradiction and infinite regress (discussed in § 1.4) that are engendered by modelling the movement, or flow, of the present with respect to B-series temporal indices. The 'movement' of the present is self-generated (or internalised) rather than externalised and rendered relative to B-series time. It moves forward through the generation of new entities and the destruction of existing entities. Consequently, the present is not dynamic by being a movement *in*, or *of*, time. The present is dynamic in so far as that which exists continues on (persists) through a process of constant creation and annihilation (real change). In this manner an independent ontological ground for objective becoming is thereby secured, and one that is metaphysically prior to both causal and temporal asymmetries.

The explanation of objective becoming given reveals the inadequacy of the term 'objective becoming'. As described, the present both continually changes and moves forward and it is this process that is referred to as objective becoming. But, as Diekemper notes, the latter is to some extent a misnomer:

> I agree with Craig that the ultimate ground of temporal asymmetry must lie in the nature of objective temporal becoming, but surely the

> presentist's rendering of this concept is not the most intuitive one. The term 'becoming' implies only creation, not annihilation. (2005, p. 239)

As advanced above, central to the notion of objective becoming is real change and this includes *both* creation and annihilation. Entities both come into and go out of existence, in the present, and it is by going out of existence that they *have existed* and are now no longer present. Objective becoming is more accurately seen as a process of dynamic unfolding, rather than simply a becoming.

8.5.1 The Asymmetry of Fixity as an Asymmetry of Ontological Dependence

The asymmetry of fixity reflects the fact that what has occurred is fixed, and settled, whereas what has yet to be is unfixed and open. Entities described as 'past' do not exist but they *have previously* existed, and, in having existed, they have been annihilated, or have gone out of existence. Entities described as 'future' also do not exist and, in this respect, there is an equivalence in the ontological status of the past and future. Nonetheless, there is an obvious asymmetry: entities described as 'future' have *not* existed, unlike those described as 'past'. This asymmetry of fixity is, I suggest below, an asymmetry of ontological *dependence,* and one that has its origin in the nature of objective becoming, in line with the account given above.

Entities described as past have gone out of existence, and something can only later go out of existence if it is, now, present. More formally, it is necessarily the case that in order for x to go out of existence, x must exist. This truth engenders a dependence between absolute annihilation and existence, and so between what has existed (the 'past') and the present. Since annihilation and existence are ontological concepts, I describe this as an 'ontological dependence'. There is, therefore, an asymmetry in ontological dependence between past and present, since what has existed must have been present. There is, however, no reciprocal ontological dependence between the present and the past; what exists may continue in existence (and so persist). This asymmetry in ontological dependence between past and present is an asymmetry that reflects the fact that the past is fixed and settled.

In contrast to the ontological dependence that holds between past and present, there is no analogous dependency between what will be (the future) and the present. This represents the fact that the future is open and has yet to be. Although neither past nor future exist (their ontological status is equivalent) there is, nonetheless, an asymmetrical ontological dependency between the past and the present, that does not obtain between the future and the present. This asymmetry in ontological dependency grounds the asymmetry of fixity between past and future, and it arises because the present, in exemplifying real, metaphysical change (which is one component of objective becoming), features absolute annihilation in addition to absolute creation.

It is conceded that this represents a non-standard use of the term 'ontological dependence', however, it is proposed as a variety of ontological dependence that relates specifically to the nature of *concrete* existence. Tahko and Lowe (2016, §.1) describe three varieties of 'ontological dependence': 'rigid existential dependence'[166], 'generic existential dependence'[167] and 'essential dependence'.[168] What is described here, however, does not align with any of *these* senses of ontological dependence, and this is because those identified by Tahko and Lowe concern dependence relations that obtain between different, *existent* entities. This leaves a void in the description of existential dependence relations that involve creation and annihilation. The dependence at issue here is that which obtains between absolute annihilation and concrete existence. In a similar vein, Ingram (2016) utilises a non-standard notion of ontological dependence which he terms 'non-rigid ontological dependence' (as discussed in § 7.6) to describe the dependence between thisnesses and their corresponding entities: 'x's thisness T exists only if x has existed' (2016, p. 2886).

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[166] 'Rigid existential dependence' refers to the existential dependence of one object or entity on the existence of another. For example, 'Sets ontologically depend on their members'.

[167] 'Generic existential dependence' is a 'more general kind of dependence' as illustrated by 'electricity ontologically depends on electrons'. This is more general in the sense that the existence of electricity depends upon the existence of a certain kind of particle, with its associated properties.

[168] 'Essential dependence' is a non-modal variety of ontological dependence related to the identity or essence of an entity, defined as follows: '*x* depends$_E$ for its existence upon *y* $=_{df}$ It is part of the essence of *x* that *x* exists only if *y* exists' (Tahko and Lowe, 2016, § 4.3).

A further potential objection may arise, which was mentioned previously. Standardly, ontological dependency is a *relation* between elements in a domain and, as such, is existence-entailing. The dependence I have described here is ontological, in that it concerns the nature of, specifically, concrete being, but it is not a relation. Rather, it is more akin to the 'one-sided existential dependence' (Ingthorsson, 2002, p.8) that was referred to as obtaining between cause and effect, under a productive account of causation (§ 7.4.4). Accounts of both objective becoming and productive causation rely on ontological notions of absolute creation and annihilation for their explication. Yet the tools required to represent existential creation and annihilation are not available within the standard classical-logical account of quantification, and this presents difficulties in providing adequate accounts that depend on these concepts. Mulder (2016, p. 36-41) and Hinchliff (2010) make similar points concerning the way in which standard logic disadvantages the presentist position. Although not coming at the issue from a presentist perspective, Crane (2011) highlights that the mainstream semantic approach to existence and quantification does not permit sentences such as 'some things we think about do not exist' to be true (2011, p. 46). Crane's solution is to regard quantification as a way of 'talking about' things (p. 58), where aboutness is meant as representation, rather than reference. In line with this a *domain* of quantification should be conceived of as a 'collection of objects of thought' (p. 64), rather than a set of existent entities.

I have no rebuttal for the objection above, other than to appeal as follows. The arguments within this thesis represent an attempt to formulate an account of presentism compatible with physical theory. The approach taken assumes the metaphysical priority of an objectively dynamic reality and regards the spacetime of relativistic physics as representing the structure of this reality. This has required that the concepts to which presentists avail themselves (such as the present, change, objective becoming, causation and persistence) are formulated purely as existential concepts that make no reference to B-series time. The formulation of presence as existence (Tallant, 2014) achieves this. Nonetheless, the presentist, who is also an A-theorist, requires recourse to the existential concepts of absolute creation and annihilation, to account successfully for real change and objective becoming, and until these find formal expression within a temporal logic the difficulties encountered in formulating an objectively dynamic reality remain.

POSTSCRIPT - MCTAGGART REVISITED

I have argued in this thesis that, to be compatible with physical theory, 'serious' presentism[169] requires a suitable ontological foundation. This is one that permits the objectively dynamic aspects of reality, indicated by tense, to be internalised in the present, and this is achieved by formulating those aspects independently of B-series time. This requires a revisionary ontological approach that is based upon the categories of concrete substance, powerful property, pure process and interaction event. In pursuing this path, I have taken serious presentism to be *primarily* a thesis about existence (in particular, a thesis that existence is objectively dynamic), rather than a thesis about time *per se*. My starting point is Existence Presentism (Tallant, 2014) and I have argued that compatibility with physical theory requires that this model is combined with a reductionist position on spacetime that regards spacetime as the structure of an objectively dynamic reality.

In closing, I draw attention to the enduring relevance of McTaggart's argument and his distinction between the A-series and the B-series. As Thomson (2001, p. 229) notes there are many who 'see things in it that they regard as true and important, or if not true, then anyway important'.

For McTaggart, any reflection on our concept of time sees that it necessarily involves change. This assumption, together with the fact that B-series relations are permanent, leads him to conclude that the A-series must be the more fundamental. Events cannot be objectively temporally ordered, as earlier-than or later-than, unless those events can alter their A-series determinations. The existence of the B-series therefore depends upon there being real (tensed) change. The second part of his argument is to conclude that the A-series is contradictory and that, therefore, time is unreal.

Although McTaggart regards change as playing a central role in time, he rejects seeing change in terms of events coming into, or going out of, existence. The reason for this is that B-series relations are *permanent* relations. This fact,

[169] A 'serious' presentist is one who subscribes to the additional thesis that tense indicates something objective and fundamental about reality.

combined with the assumption that relations imply the existence of their relata, means that it just cannot be the case that where an event, *x*, stands in the relation of *earlier than* to another event, *y*, it is also the case that *x* does not exist (Ingthorsson, 2016, p. 36). Ingthorsson (2016) also highlights the significance of McTaggart's prior metaphysical commitments in interpreting his arguments. In particular, his Hegelian notion of reality (including time) as an absolute and perfect 'whole' counts against regarding change in terms of absolute creation or annihilation. Change, for McTaggart, can therefore only be the gain or loss of A-series determinations (pastness, presentness and futurity).

The approach taken within this thesis rejects the standard definition of change, as different properties at different times, on the grounds that this disadvantages the presentist because the 'different times' underpinning the standard models of both change and persistence are B-series times (§ 5.4.3 and 5.5). Change is instead reformulated as 'something coming into existence and/or something going out of existence' (§ 5.7.2). In the case of *qualitative* change this is the gain or loss of properties *simpliciter*; in the case of *substantial* change this is a gain or loss of entities. *Pace* McTaggart, the essence of change for the serious presentist is absolute creation or annihilation. It is this formulation of (real, metaphysical) change, together with a reformulation of persistence (as 'continuing existence', § 5.4.5) that characterises what it is for reality to be objectively tensed, and allows the fundamentality of the A-series to be asserted.

The present moves on, or objectively flows, not with respect to B-series time but by characterising the opposing features of real, metaphysical change and persistence (§ 5.8.1). It is this dual nature of the present that provides the mechanism to *internalise* the dynamic aspects of reality and render them independent of B-series time. This objective flow, characterised by the present, underpins the changing A-series determinations of objects and events. The fundamentality of the A-series therefore arises from the nature of the present: the present, in exemplifying both real, metaphysical change and persistence, is objectively dynamic. As McTaggart suggested, the A-series is both fundamental and is required for there to be 'real' change.

McTaggart also maintains that the B-series must, in some manner, be dependent upon the A-series. This has also been argued for in this thesis. I concluded in Chapter 2 is that it is beneficial for the presentist, who seeks a model compatible with physical theory, to adopt a reductionist account of B-series time that equates time with the structure of an objectively dynamic reality. Achieving this goal requires a suitable ontological model for presentism, which was developed in Chapter 6. The second tier categories of the model - pure process and interaction event - reflect the primitive nature of persistence and real, metaphysical change, respectively, and provide the mechanism for the internalisation of the dynamic aspects of reality. At the fundamental, physical level that which exists (propertied substance), and so is present, consists of pure processes and their interactions (interaction events).

I have also argued that the categories of pure process and interaction event align, in a functionally relevant manner, with the primitive elements in Belkind's (2012) Primitive Motion Relationism from which the structure of (flat) relativistic spacetime can be derived. If the argument for a functional alignment can be supported, then spacetime intervals (and so the fixed B-series relations between events) arise as the structure of an objectively dynamic reality.

The conclusions of this thesis, therefore, align with these two strands of McTaggart's argument: the fundamentality of the A-series and the dependence of the B-series upon the A-series. However, McTaggart's conclusion that the A-series leads to contradiction can be avoided if his assumptions concerning change are rejected. The fundamentality of the A-series requires that change is formulated independently of (B-series) time, and this means that change, at the metaphysical level, is provided by absolute creation and annihilation.

This thesis has outlined an approach towards establishing a model of serious presentism compatible with physical theory. Under this model serious presentism is a theory of (dynamic) existence, rather than a theory of time. Consequently, the presentist can happily cede that the B-theory provides an adequate theory of 'time', an adequacy that is demonstrated by the predictive success of our best scientific theories. This 'time' just is the *structure* of, and proceeds from, an objectively dynamic existence. Similarly, the serious presentist has no reason to fear the 'disappearance of time' at the fundamental level, as is indicated by developing theories of quantum gravity. The 'time' that disappears is simply B-series time, the time that emerges (at supra-Planck levels) as the structure of an objectively dynamic reality.

APPENDIX 1 – REFERENCE FRAMES IN MINKOWSKI SPACETIME

The Concept of a Frame of Reference

In general terms a frame of reference in physics is a set of spatial and temporal coordinates (a coordinate system) together with a set of physical reference points (e.g., events) that serve to anchor or locate the abstract coordinate system in physical reality. It is with respect to the physical reference points that measurements of spatial and temporal intervals can be standardised.

For observers in relative motion a reference frame is defined with respect to each observer and is one in which they are at rest. Transformation equations are defined which allow the coordinate descriptions (or measurements) applicable to events in one reference frame to be translated (or transformed) into those which describe the event in another reference frame (from the point of view of the observer at rest in that frame). Inertial reference frames are reference frames moving with a uniform, relative velocity with respect to each other; they are frames in which Newton's first law, the Law of Inertia holds.

Reference Frames in Minkowski Spacetime

Reference frames for observers in relative motion are described within Minkowski spacetime in the following way.

For an observer (A) at rest relative to an object being measured the spatial (x_A) and temporal (t_A) axes are shown as perpendicular to the origin. The velocity of light, in that reference frame, is shown by convention as having a unit velocity of 1 (indicated by the red line in Figure A(i). It therefore bisects the two, orthogonal coordinate axes.

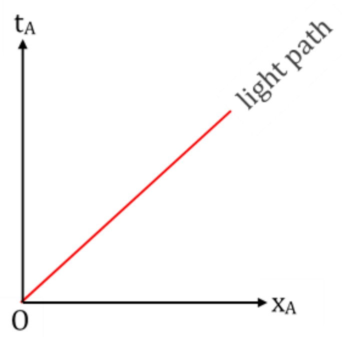

Figure A(i) *– Reference frame, S, for an observer, A, at (relative) rest.*

Since velocity is defined as Δx/Δt, in order that the velocity of light is constant for all observers in all reference frames (as required by the STR), reference frames moving with relative velocity with respect to the rest frame (shown as primed frames) are tilted at equal angles to the path of light (also referred to as a 'light cone'). The greater the relative velocity of the observer, the more acute the angle, thus C's reference frame is moving with greater velocity, relative to A, than B's frame in Figure A(ii).

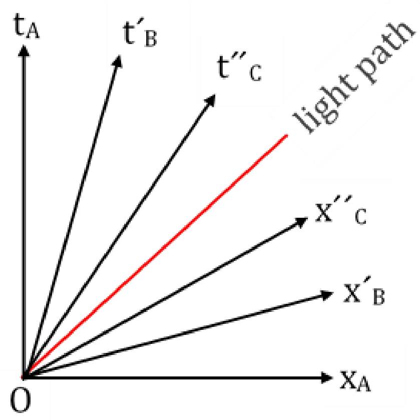

Figure A(ii) *– Reference frames, S´ and S´´, for observers, B and C, in relative motion with respect to A.*

It is the relative tilting of the coordinate axes of observers in relative motion (due to the invariance of the velocity of light) that leads to the result that any measurement of length (a spatial interval) made by observers in relative motion at the *same time* will differ. This is indicated by the projections of the length of the rod onto the different coordinate axes (x'_B and x_A) in Chapter 3, figure 3.4. Similarly, any measurement of duration (a temporal interval) made by observers in relative motion at the *same place* will also differ. It is the invariance of the velocity of light that determines the spatiotemporal structure of reality and the existence of relativistic kinematic effects (length contraction and time dilation).

APPENDIX 2 - SUMMARY, KEY DEFINITIONS & AXIOMS OF BELKIND'S MODEL

In this Appendix I set out the key definitions and axioms of Belkind's Primitive Motion Relationalism (Belkind, 2012, pp. 59-91) of relevance to Chapter 6, and summarise the main arguments underpinning his derivation of both Galilean and Minkowski spacetime.

Primitive Motion Relationalism takes uniform, unidirectional motions (PUMs) as the basic entities of spacetime. These are undefined primitives. Illustrative examples of PUMs are the motions of free particles, isolated systems and light signals.

Definition 1 (Event): For primitive motions, α and β, an event is defined as an intersection between PUMs ($\mathbf{E}\alpha\beta$). $\mathbf{E}\alpha\beta$ is a two place relation between PUMs and is true if the motions intersect and false if they do not. For flat spacetimes an event, p, is *identical* with a true relation $\mathbf{E}\alpha\beta$ (for curved spacetimes there will be more than one coincidence point). Coincidence relations are irreflexive ($\neg\, \mathbf{E}\alpha\alpha$) and symmetric ($\mathbf{E}\alpha\beta \leftrightarrow \mathbf{E}\beta\alpha$).

Once events are defined, the spacetime is constructed from the geometric relations between events. Relations between pairs of *events* (such as the determinateness relation below) are therefore four-place relations between PUMs.

Definition 2 (Parallelism): This comprises two conditions on motions, α and β, being parallel ($\mathbf{P}\alpha\beta$):

1. The motions do not intersect $\mathbf{P}\alpha\beta \rightarrow \neg\, \mathbf{E}\alpha\beta$

2. Parallelism is a transitive relation $[\mathbf{P}\alpha\beta \wedge \mathbf{P}\beta\gamma] \rightarrow \mathbf{P}\alpha\gamma$

PUMs are parallel where motions have the same velocity and direction.

Axioms of Incidence: A set of four incidence axioms guarantees that events (coincidences) arise for motions:

I 1. Every PUM is intersected by at least one other

I 2. For every motion, α, there is an intersection between two motions which is not on α

I 3. For every motion, α, intersected by another motion, β_1, there is another motion, β_2, parallel to β_1 and which intersects α

I 4. If a motion, α, intersects another motion, β_1, it intersects all other motions parallel to β_1

Axioms of Determinateness: A relation of determinateness (**D**pq) is defined as a two-place relation between events[170] on a particular motion, where event, p, determines event, q. The determinateness relation describes an asymmetrical causal relation between events along motions. There are two axioms of determinateness:

1. Any pair of events p and q belonging to a given motion α stand in an anti-symmetric causal relation – either p determines q or q determines p, but not both.

2. Transitivity of determinateness relations – if p determines q and q determines r then p determines r. (Note: this does not require that the 3 events belong to same motion).

Further axioms of 'betweenness', 'congruence' and 'continuity' are also articulated, which establish relations between events.

The generation of events in this manner allows for the decomposition of motion intervals into spatial and temporal components. Motion intervals and relative velocities (i.e. the 'angle' between PUMs) provide the basic metrics allowing a Galilean spacetime to be constructed.

The addition of Einstein's Light Postulate (considered as a Relativistic Paradigm of Uniform Motion, or RPUM) allows Belkind to derive the flat, relativistic, spacetime of STR in a similar manner. The latter starts with presupposition of two privileged sets of parallel motions, one (ν_1) represents light waves going in

[170] Equivalently, this is a four-place relation between PUMs.

one direction, the other (ν_2) light waves going in the opposite direction. The reconstruction of the Light Postulate amounts to the assumption that the motions, ν_1, and, ν_2, have equivalent motion intervals, regardless of the set of parallel motions used as a reference. In other words, light-waves, as a privileged class of motions, provide an absolute standard of motion intervals. As Belkind states, the derivation of flat relativistic spacetime from Einstein's light postulate (employing RPUM as a basic entity) shows that Einstein's restricted Principle of Relativity arises as a natural consequence from the assumption of the fundamentality of uniform motion, and its priority over spatiotemporal relations. This is an important benefit of Primitive Motion Relationism. Under Einstein's STR this principle has to be assumed as a fundamental axiom in order to derive the structure of spacetime. The successful derivations of both Galilean and STR spacetimes by Belkind's theory grounds an explanation for the Principle of Relativity, and its role in kinematic and dynamic laws.

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